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# Heating Piping & Air Conditioning

DESIGN
INSTALLATION
OPERATION
MAINTENANCE

FEBRUARY ★ 1946

INDUSTRIAL
COMMERCIAL
INSTITUTIONAL AND
PUBLIC BUILDINGS

Vol. 125 — Journal Section of the American Society of Heating and Ventilating Engineers

*This reception room mural—both decorative and informative—dramatizes the world-wide job of the air conditioning engineer*

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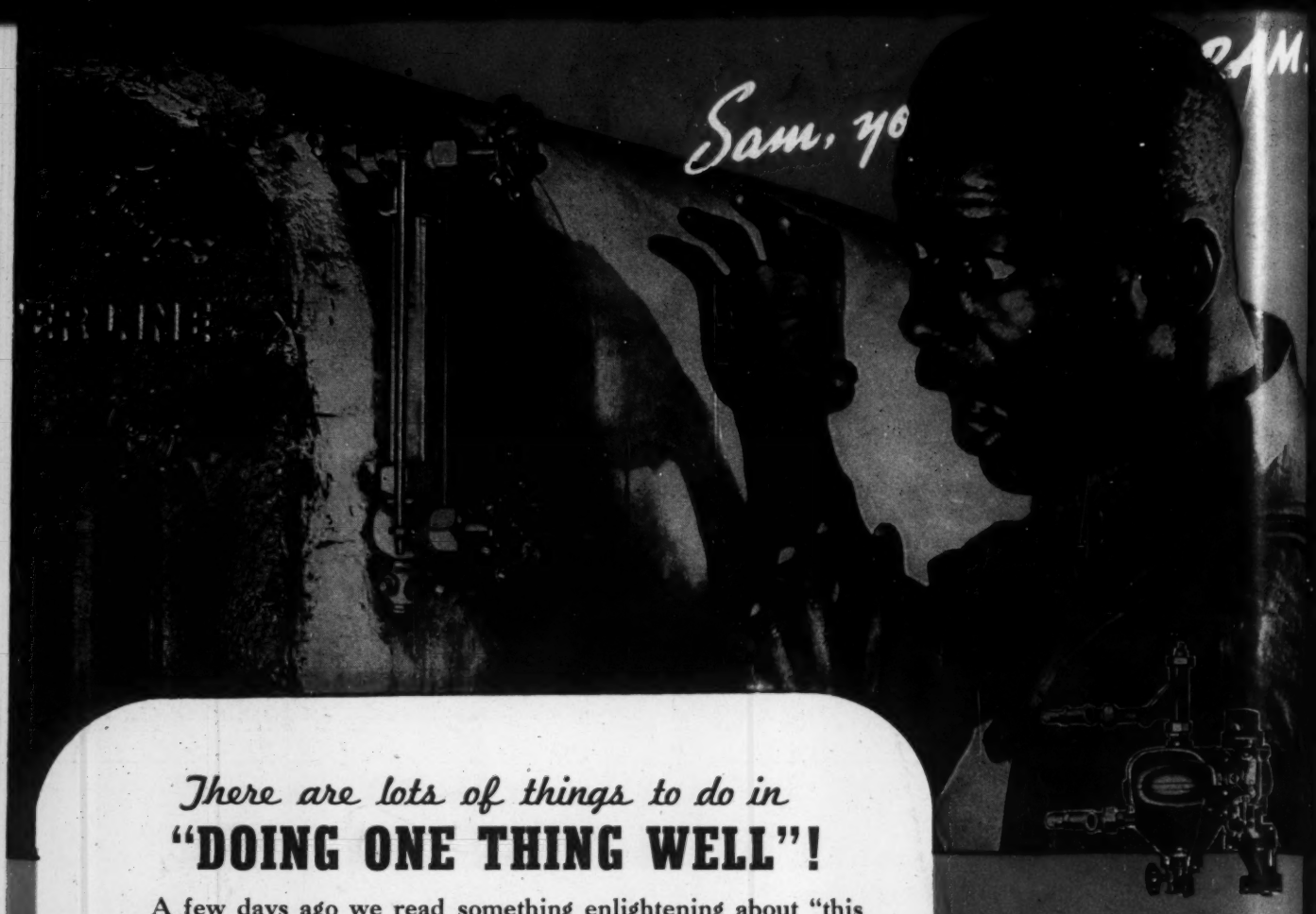


*There are lots of things to do in*

# "DOING ONE THING WELL"!

A few days ago we read something enlightening about "this modern world." It wasn't one of those articles about atom splitting; it was the preface to an automobile instruction book printed in the year 1906! It told the proud owner: "While your 'Surrey Type' Auto has attained test speeds of 30 miles per hour, the sane driver will not want to hazard the break-neck speeds now possible in *this modern world*." (The italics are ours.)

Well! . . . wasn't 1906 modern? Long before 1906, and every year since, people have been talking rather arrogantly about "this modern world." We talked it very excitedly at the end of World War I, and we are talking it still more excitedly now. But the fact is that "this modern world" is only a state of mind—today's mind.

Too often manufacturers become smug and complacent about their so-called "modern" products. Those who avoid this state of mind—who realize that "modern" is merely the designation of the point reached today—are always easy to identify. They are simply the fellows who keep on improving things!

We have tried to avoid the "arrived" state of mind. "Doing One Thing Well" hasn't simply meant making good equipment and letting it go at that. That is why our record is studded with developments like the first Quick-Hook-Up, the first cool feed valve, the first packless feed valve, the first stainless steel valves, and so on down the ever-lengthening list.

And we're still at it, and we'll always be at it, as evidenced by the boiler water feeders and low water cut-offs illustrated here. Just now, the big problem is to make them fast enough, but this is only a passing condition.

McDONNELL & MILLER, *Inc.*, 1316 Wrigley Bldg., Chicago 11, Ill.

*Doing One Thing Well* REG. U. S. PAT. OFF.

Your Jobber Stocks Them

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## *Boiler Water Level Controls*



No. 47-2 Feeder-Cut-off Combination [illegible] boilers below 5000 sq. ft.; maxim[illegible] steam pressure, 25 lbs. Quick-Hook [illegible] for speedy, correct installation.

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No. 150 Water Level Control for b[illegible] of any size with steam pressures u[illegible] 150 lbs. Used as feed-pump c[illegible]ntrol; [illegible] water cut-off; low water alarm, or [illegible] combination of these functions.

# Heating Piping & Air Conditioning

with which is merged the Aerologist

Design, Installation, Operation, and Maintenance: Industrial, Commercial, Institutional, and Public Buildings



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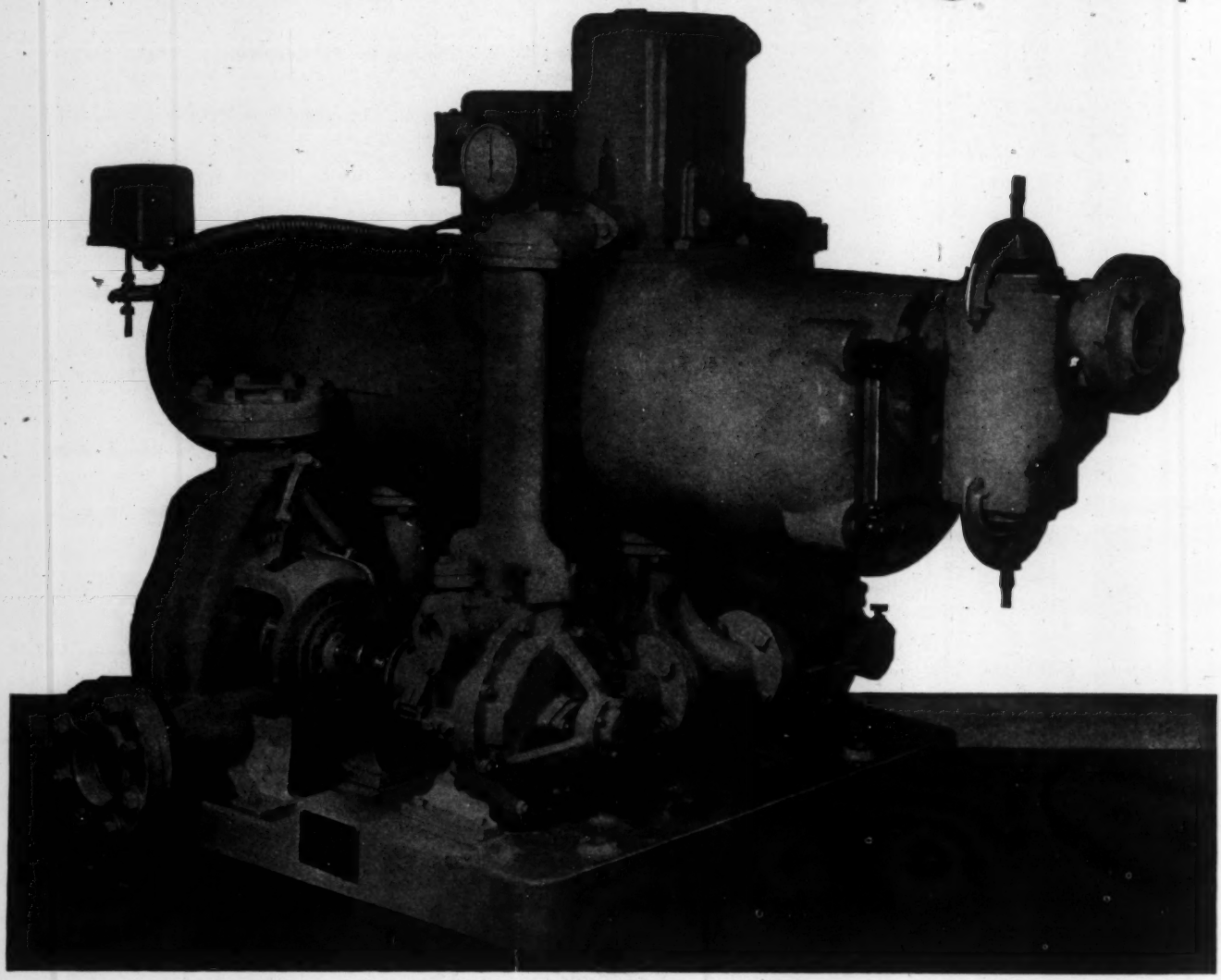
# Where Heat Must Not Fail– Install this SAFE Heating Pump!



In Hospitals, Greenhouses, Schools, Public Buildings, Theatres, wherever heating systems must not fail, install the Nash Vapor Turbine, for it is entirely independent of electric current failure, and continues to operate as long as there is steam in the system.

More than that, the Vapor Turbine is a most economical pump, for the elimination of electric current does away with current cost, the largest single item in the operation of an ordinary return line heating pump.

Greater savings still are effected by the Vapor Turbine in the system, for the reason that this pump operates continuously. It is the only pump that can do this with economy. Continuous operation means uniform circulation, and uniform circulation saves steam.

The Nash Vapor Turbine has but one moving part, rotating in the casing without metallic contact, and requiring no internal lubrication. Quiet, compact, and trouble-proof. Bulletin A-290 is free on request.

## THE NASH ENGINEERING COMPANY

**SOUTH NORWALK, CONNECTICUT, U. S. A.**

***Amount of Interest Shown at Engineering Meetings Proves***

# RADIANT HEATING "HOT" SUBJECT

IF IT WERE necessary to pick the one subject which is receiving the most attention from heating engineers at the present time—basing one's vote on the discussion and "conversation" one hears at meetings and conventions of engineers, contractors, and architects—probably radiant heating would be the winner.

For example, at the annual meeting of the American Society of Heating and Ventilating Engineers in New York City last month, there was but one paper presented on this subject; however, this paper probably came in for more extended discussion than did any of the other nine. And in the "corridor conferences" outside the meeting room, it seemed easy—sometimes too easy—to get into a conversation about design methods and installation details for radiant heating.

Various methods of fabricating and prefabricating coils of various materials (copper, stainless steel tubing, steel, and wrought iron) and for various building locations were mentioned, and new manuals (either just issued or about to be issued) to facilitate the design of such systems were in evidence. One consulting engineer had an extensive series of beautiful color films, illustrating the construction steps in the installation of a floor heating system for an industrial building. A luncheon speaker—a prominent architect—went "all-out" for radiant heating.

At the recent Penn State housing conference, Charles A. Hawk, Jr., of A. M. Byers Co., presented a paper on radiant heating which attracted a good deal of favorable attention. The following paragraphs, in which he reviews a number of applications of this heating method, have been taken from this paper:

### Two Story School

The earliest true radiant heating system found so far in this country was installed in the floors of a two-story, four-room schoolhouse in a town which is now part of Gary, Ind. This schoolhouse was built in 1909 and the heating system served in an unusually satisfactory manner for about 25 years. From this rather recent beginning, a high degree of ingenuity on the part of many independent heating men has developed the germ of the underlying physical principle into many applications and diversified fields. To illustrate the character of modern application and to report on how other heating designers are making use of this physical principle at the present time, the following case histories are cited.

### Textile Mill Dye House

An addition to a large textile mill in Canada is a good example of the application of the radiant heating system to meet specific requirements. A dye house comprising part of this mill is roughly 100 by 125 ft in plan, with a 20 ft ceiling height to the underside of a flat concrete slab roof. The floor of this building is covered for perhaps 75 per cent of its area by large sunken dye vats. During operation of the dyeing process, the boiling water in the vats gives off more than enough heat and moisture to maintain comfort conditions in the space. The principal problem during these periods

**IT'S PRETTY difficult to do much "trend spotting" in an engineering field, where the selection of any one method must come down to hard facts and be based on detailed engineering analyses of specific cases. Then, too, engineers and contractors—like everyone else—are inclined to talk most about the newer developments, to the exclusion of longer-established practices, as it is the newer things they need more information about. We don't mean to imply, by the great amount of information we've been publishing about radiant heating, that there is a universal trend toward it, or (for that matter) that it's more important than other methods of heating. As pointed out in this article, though, there is a lot of interest in the subject and a big demand for practical data on it—and it's part of our job to meet that demand. In the final analysis of any particular installation, of course, its advantages and disadvantages must be weighed against other types of heating, in the light of experienced engineering and practical judgment, for the job to be done.**

is to evacuate hot air and water vapor sufficiently fast to maintain comfort. During shutdown periods, it is necessary, however, to introduce some heat into the building to prevent freezing in a climate which frequently hits —30 F. The designing engineer elected to place radiant heating coils carrying hot water in the roof slab. In operation, experience has shown that the warming effect of these heating pipes prevents condensation on an otherwise cold ceiling surface and carries temperatures in the building at 40 F over weekends or other nonoperative periods.

### Weaving and Spinning

An adjoining building at this mill is devoted to weaving and spinning operations and contains two floors, each with a 15 ft ceiling, covering an area approximately 125 ft square. The owner's previous experience with other similar structures indicated that periodic and costly maintenance was required with conventional heating. By turning to a floor type radiant heating system on the first floor and a ceiling type heating system on the second floor of this building, the maintenance charges were eliminated and a more uniform temperature and relative humidity could be maintained. To accurately convey the size and complexity of this installation, it should be noted that the total cost of these two buildings was approximately $300,000, the heating contract for the radiant heating system running to approximately $23,000.

A much smaller but more widely based application for radiant heating systems is being uncovered in poultry brooding operations; this applies equally to chickens, ducks, and turkeys. The author has recently investigated one very large application on Long Island devoted exclusively to the raising of that rare dinner table treat, the famous Long Island duck. About two years ago one of the larger duck farmers on Long Island lost a large brooder house because of fire. When rebuilding it, a floor type radiant heating system in the concrete slab was included. The results since that time have been so successful that seven other similar houses have been constructed and the new operation has radically changed the complexion of this farming operation.

### Poultry Brooding Operations

Before going further it should be noted that the duck farming operation, as carried out on Long Island, is big business and consequently points which may seem otherwise minor take on considerable importance when it is realized that any one of several of these farmers will ship one-quarter of a million ducks per year at about $2 per head.

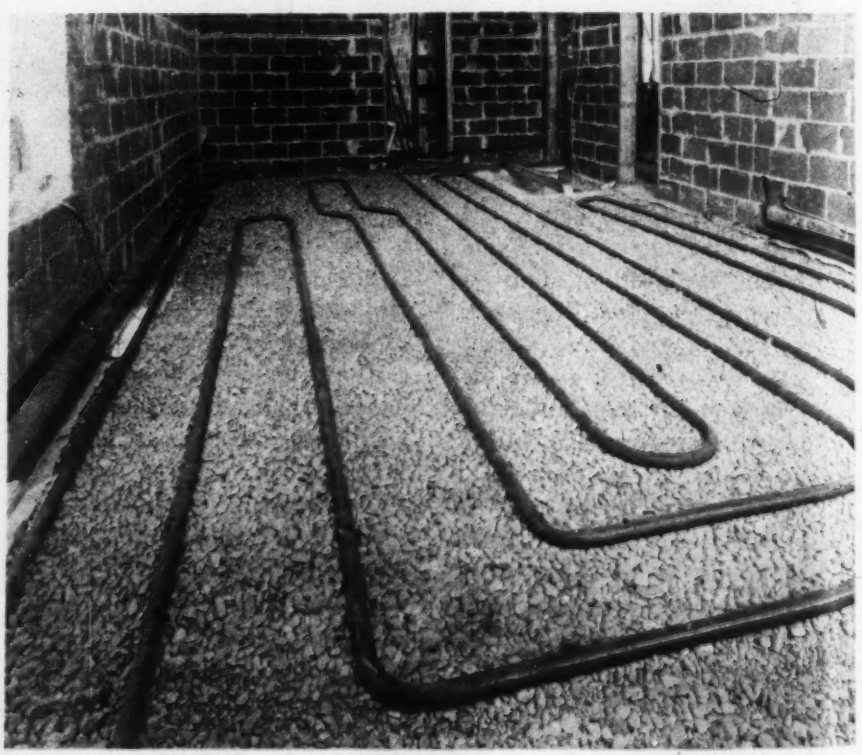
The brooder houses referred to in this instance measure approximately 30 by 150 ft in length and will house approximately 7000 ducklings at one time. During a 10-week growing cycle, it was found that an average weight increase, winter and summer, of approxi-

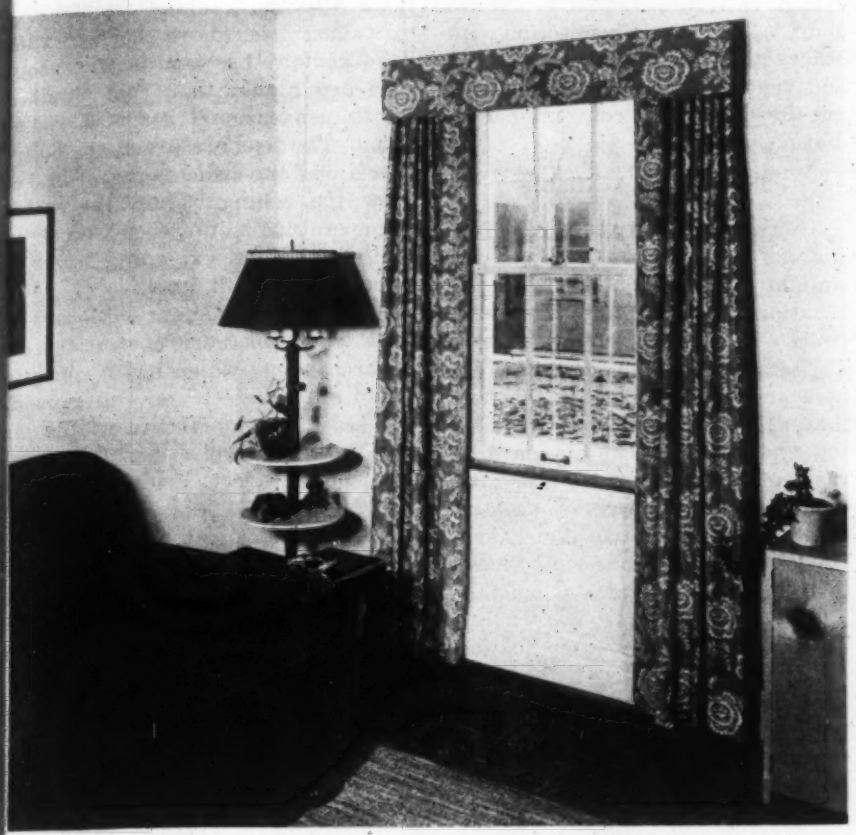
## RADIANT HEATING FOR TELEPHONE EXCHANGE

To install the radiant heating system at a rural telephone exchange building, sinuous coils of wrought iron pipe were fabricated on a hydraulic bending device and with portable welding equipment. These coils were placed on a 6 in. gravel fill covered with waterproofing paper. Six inch wide strips of 1 in. insulation were laid under the pipes. A 4 in. concrete slab was poured over the heating coils and the fill. Asphalt tile finish flooring was cemented to the concrete slab throughout. Approximately 254 ft of 1½ in. and 731 ft of 1¼ in. pipe was used for supply and return mains and individual floor coils. The floor coils were spaced on 15 in. centers in most rooms. The entire system was tested hydrostatically before the slab was poured to insure tightness of all welds and that none of the pipe was damaged during installation. The supply mains from the utility room were run around the exterior walls of the building to give these areas the benefit of the hottest water because heat losses are usually the greatest at slab edges and through footings. Insulation was placed between the slab edges and the f otings to interrupt heat flow through this path of high conductance.

Designed to meet an outdoor temperature of 0 F and maintain an indoor temperature of 70 F, the system is controlled by room-air wall thermostats which activate circulator pumps. Two pumps are used, one for the operating room and another for the living quarters, but they are interconnected so that if one fails the other can carry the entire load. An oil fired boiler, with aquastat controls set for 130 F water, is used for the heating plant. Balance cocks installed on feeder lines for individual room coils may be adjusted to provide desired comfort conditions in the various rooms. The entire heating system, including the boiler, cost approximately $1.18 per ft.

This scene is in the operating, or switchboard, room and the pipe runs have been offset to accommodate relay and battery charging panels. Cable pit is top right.





**Baseboard radiation permits full use of floor space**

mately ½ lb could be attributed to the healthful conditions created by the radiant heating system. In addition, the maintenance of the proper floor surface—usually straw or woodchips — was made much simpler and considerable labor savings resulted. Of great direct importance is the fact that the fire hazard in such structures has been almost entirely eliminated due to the construction of a central boiler plant and the elimination of many individual and sometimes unsafe heating devices located on the floor of the brooder houses.

### Explosives Manufacturing

During the war, explosives manufacturers experimented with radiant heated curing ovens with excellent results. Based on these experiments, a considerable number — probably somewhere around 200— of these curing rooms have since been constructed. During the curing operation, it is necessary to maintain a very exact temperature control in the neighborhood of 140 F and, at the same time, produce these temperatures with equipment which will be just as safe as it is economically possible to devise. The experiments referred to sought to establish the control accuracy available with various types of heating coils.

After rather exhaustive study, the floor type coil was selected and has been generally used. Over an 8 hr operating cycle in extremely cold weather it was found possible to maintain 140 F in these buildings without varying more than 0.5 F from the thermostat setting. The obvious safety advantages, inherent in complete concealment of all heating appliances, are of course very desirable in such hazardous work.

Many municipal building programs at the present time contemplate the construction of new hospitals and mental institutions. In many of these institutions radiant heating systems are being planned. Largely because of the complete concealment characteristics of radiant heating systems, it is possible to create clean and safe environments for the patients and inmates of these institutions.

### Snow Melting

In closing, attention is called to the presence of an "infant" idea which shows signs of growing into a very important device in modern building—the underground snow-melting system. While this does not incorporate to any appreciable degree the transmission of heat by radiation, the fabricating and designing technique is somewhat related and, as a matter of fact, has its roots in radiant heating development.

Without going into the economics involved in such a system it is sufficient to say that the removal of snow by heat appears to be very practical for any locality where an output of money is required for snow removal. Such applications can be found at airports, department stores, railroad passenger and freight platforms, industrial and residential driveways, etc. Initial cost is a rather sizable item and can be roughly estimated, for most communities at something between $0.30 and $0.50 per sq ft of surface, depending on local conditions. However, operating costs are exceedingly low. The usual practice is to design for a melting rate of 1 in. per hr of snow. On the basis of coal at 12,000 Btu per lb and $5 per ton, 1 in. of snow can be removed from 1 sq ft of surface for approximately 3/1000 of one cent. To put this cost another way, a 6 in. snowfall on an airport runway 5000 ft long and 150 ft wide could be removed at a fuel cost of $135. This could be done in 6 hr time, almost entirely automatically, leaving a perfectly dry, clean runway.

### Radiant Baseboard Heating

Heating by means of radiant baseboards was described by three speakers at a meeting of the ASHVE's Illinois chapter in Chicago last month. The speakers were John P. Magos, director of research, Crane Co.; M. W. McRae, research engineer, Crane Co., and Warren S. Harris, research professor, University of Illinois. The large attendance at the meeting and the questions from the floor after the formal talks indicated keen and intelligent interest in the subject.

Among the advantages of radiant baseboards stressed by the speakers were comfort for occupants of rooms in that floor temperatures are higher and under-ceiling temperatures are lower; warm floors;

elimination of drafts; cleanliness; and full utilization of floor space.

Mr. Magos, the first speaker, reviewed early steps in the development of the radiant baseboard. He said that in 1905 a patent was issued for a heating device consisting of a pipe covered with sheet metal. Several other patents were issued between 1905 and 1925.

In 1925, Professor A. C. Willard of the University of Illinois, who was then head of the department of mechanical engineering, asked two of his associates, A. P. Kratz and M. K. Fahnestock, to study the effect of low radiators. High radiators in a room were replaced with low radiators with results which directed the attention of the heating industry to the advantages of a low source of heat, well distributed along the outside walls of rooms.

Mr. McRae said that no special construction is required for use of radiant baseboards. If they are to be installed in a new building, conventional baseboards are omitted on the walls where the unit is to be located. If they are to be installed in an existing structure, the baseboard is removed and replaced with the unit, which comes in various lengths in multiples of a foot.

According to Mr. McRae, there is no need for any special calculations to design a radiant baseboard installation. Heat losses are figured in the ordinary way, and divided by the rating per lineal foot to determine the required amount of baseboard radiation needed in a room. He said that the ratings for the radiant baseboards are 300 and 425 Btu per lineal foot for the low and high heights, respectively, and for the radiant-convector baseboards, are 500 and 650 Btu, respectively. The same size runouts from risers as with conventional radiation are used.

Usually, Mr. McRae explained, there will be ample room for the radiant baseboard along the outside walls of a room. If there is not enough room, a certain percentage of the total length of radiant baseboard may be installed on the inside walls; this percentage should not exceed approximately 25 per cent, except in unusual circumstances, he indicated. If the percentage is too high, there are likely to be downdrafts on outside walls, he said.

It is entirely practical to use radiant baseboards in connection with other radiators. Piping, valving, and venting of radiant baseboards are the same as for conventional radiation.

### Two Types Available

There are two types of cast iron radiant baseboards. One is a full radiant panel; the other is a combination radiant and convector panel. These units will vary from 1¾ to approximately 2 in. in thickness and are installed at the floor line with standard wood molding, top and bottom. The standardization program provides for two heights for each type of unit. It does not specify actual dimensions. Units now being made vary from 6 to 10 in. high, exclusive of molding.

It is preferable to use radiant baseboards with hot water heating, either gravity or forced. They can be used with two pipe steam, but not with one pipe steam because of venting and draining problems. Mr. McRae expressed a personal preference for hot water when using radiant baseboards.

Professor Harris said that the performance of radiant baseboards was studied in the IBR research home at Urbana during the last two winters. The results, which were excellent, are set forth in detail in bulletin No. 358 of the U. of I. engineering experiment station [also see Performance of Radiant Baseboards in Research Home, by A. P. Kratz and W. S. Harris, ASHVE Journal Section, Heating, Piping & Air Conditioning, January, 1946].

The outstanding feature of the radiant baseboard is the low floor to ceiling temperature differential, Professor Harris said. This was only about 2 deg at an outdoor temperature of zero and an indoor temperature of 72 deg at the 30 in. level. Professor Harris also pointed out that the average temperature obtained 3 in. above the floor with the radiant baseboards was about 1.4 deg higher than that obtained with conventional recessed radiation. The temperature at the 60 in. level was the same as that 3 in. below the ceiling. Thus, the entire temperature difference occurred within the zone extending from the floor to the 60 in. level.

The use of a radiant baseboard in the first floor washroom of the research home, which has a concrete floor laid directly on the ground, raised the temperature of the air at the floor level 6 deg. Commenting on this fact, Professor Harris said:

"A cold floor is a major factor in contributing to discomfort in otherwise well-heated rooms. Hence the tendency to produce a warm floor may be regarded as an important attribute of radiant baseboards."

The wall surface temperatures when radiant baseboards were used varied from 92 deg directly above the unit to 72 deg at the 60 in. level. The temperatures at these two points, when recessed radiators were used, were 70 and 72 F respectively.

### Fuel Consumption

The fuel consumption showed no appreciable variation when radiant baseboards are used in place of recessed radiators. The response of the heating system during the warming-up cycle was essentially the same with baseboards as with conventional recessed radiators.

Professor Harris commented particularly on the cleanliness of heating by means of the radiant baseboard after a complete heating season of approximately nine months.

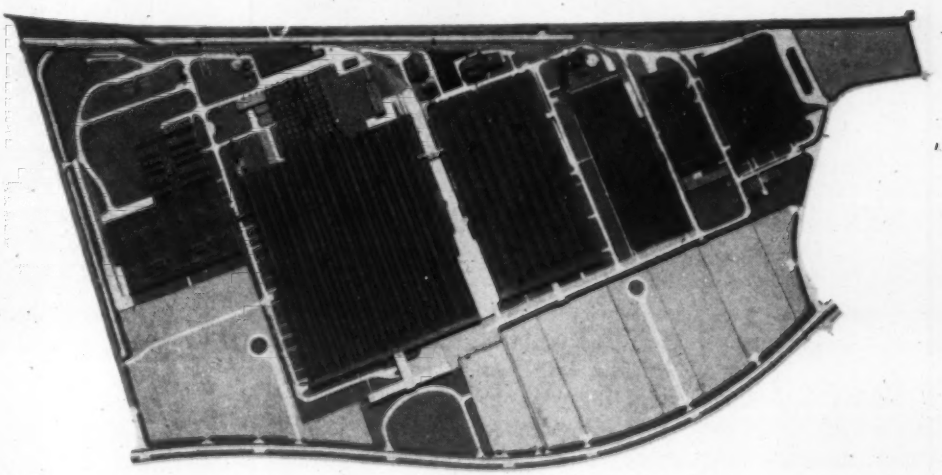
Professor Harris said that the tests were conducted with a gravity hot water heating system with maximum boiler water temperature of approximately 200 deg.

In answer to a question from the floor following the formal addresses, Mr. Magos said that he had observed no effect on the plaster from radiant baseboards. He said that in the installation of a radiant baseboard, a sheet of aluminum foil insulation or good building paper should be placed between the unit and the plaster and the top of the paper should be folded over the unit and covered with a molding.

COSTS 1½c PER MAN-HOUR

# Operating and Maintenance Charges for Air Conditioning Machine Shops

***H. B. Lammers, Assistant Plant Engineer, Compiles Cost Data on Heating, Ventilating, and Air Conditioning Huge Plant of Wright Aeronautical Corp., Lockland, Cincinnati, Ohio***



**This model of the plant indicates something of its size. The refrigeration tonnage for the jobs described amounted to 9301 tons, but was handled—due to scarcity of equipment—by 6000 tons of capacity, possible on account of storage effect**

MUCH HAS BEEN written about the air conditioning (including heating, ventilating, and cooling) of public buildings, such as theaters, office buildings, restaurants, etc., and about many applications in industry—textiles, printing, candy, etc. However, very little has been published regarding the cost of operation and maintenance of such installations.

### Why Air Conditioning Is Necessary

Air conditioning of machine shops and airplane assembly plants became important during the war because of: (1) blackout buildings, (2) large roof areas due to mammoth one-floor structures, (3) tremendous horsepower used in driving machine tools, (4) other internal heat loads, such as heat treating, etc., (5) thousands of kilowatts used in artificial lighting, (6) thousands of people employed in such areas, and (7) the necessity of providing proper ventilation.

The prevailing summer weather conditions in the Lockland, Ohio, area were also a determining factor in providing air conditioning for the Wright Aeronautical Corp. machine shops. Weather in Cincinnati is extremely variable and it is not uncommon to experience outdoor temperature changes of 25 to 30 F in one hour's time and 30 to 50 F as a normal day's deviation. In summer, outdoor temperatures of 90 to 105 F are everyday occurrences, together with relative humidities of 85 to 95 per cent. For instance, during the summer of 1944 the temperature of 90 F was exceeded on 54 days.

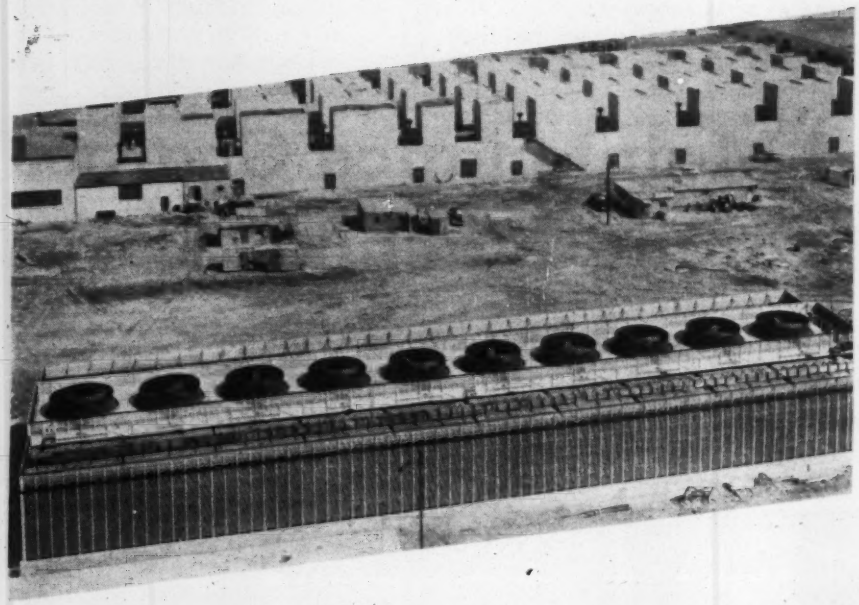
Because of manpower shortages and war production schedules, long working hours and overtime were necessary, thus producing excessive fatigue and absenteeism unless healthful and comfortable working conditions were provided.

It was considered necessary to minimize dust and dirt which might be brought in by the ventilating equipment along with the outside air, as well as that generated within the structure, such as oil and fumes, in order to produce the best in workmanship. The air was therefore filtered in order to make possible a finished product as close to perfection as possible.

The manufacture of a finished product made up of a multitude of precision parts demands the best in air conditioning. Moreover, it was expected that air conditioning would maintain a high degree of efficiency of the workers through the hot, humid summer months and maintain maximum production without interruption, and thus meet the ever increasing demand for more motors and planes.

### 40 Acres of Building Space Under One Roof

The original air conditioning installation was designed for the center machine shop, assembly, test, and office buildings. The area of



**Condensing water is supplied by a cooling tower, water being pumped through the refrigerating and steam condensers in series. The five 1200 ton centrifugal refrigeration compressors are driven by steam turbines**

these buildings approximates 40 acres under one roof. The building is approximately 1300 ft by 1100 ft and it has attached to it a two-story building 60 ft by 320 ft joined to the factory by an annex or connecting-link two-story building 50 ft by 500 ft.

The above plant was the largest single story building ever built in the United States (or, perhaps, the world) up to that time (1941). One can get some conception of its size when it is realized that it is large enough to accommodate all the major league baseball games and still have room left over to accommodate the Army-Navy football game with 50,000 spectators. Attached to this building is a group of test cells, 72 in number, the overall size being 406 ft by 380 ft.

The main building has a basement in which are the cafeterias, lunchrooms, locker rooms, etc., necessary to provide service for a large number of workers. It was anticipated that the above facilities and buildings would provide employment for approximately 15,000 people.

The air conditioning system designed for this plant has a capacity of 6000 tons and is somewhat unique in that it combines a hot water circulating heating system with a cold water circulating system for cooling. It is so arranged that either hot or cold water can be pumped through the same system of piping. This system is augmented by a series of unit heaters and radiators using low pressure steam placed around the exterior walls and openings for additional control of wall radiation. Wash and locker rooms are not cooled, but are ventilated.

The large amount of air required for ventilation would introduce a considerable quantity of dirt and foreign matter which would be injurious to the engines and interfere with production. Therefore, oil filters of the automatic continuous rotating type were installed, which eliminated the necessity of changing and washing filters at frequent intervals. This reduces maintenance cost and appreciable savings are thus affected.

The refrigerating equipment consists of five centrifugal compressors of 1200 tons each, steam turbine driven. These were the largest compressors of their type up to the time they were installed.

Located in the overhead trusses are 70 platform units equipped with coils through which both chilled water for cooling and dehumidifying and hot water for heating is circulated from the central plant.

**Table 1—Air conditioning design data and conditions**

| | Cooling Inside | Cooling Outside | Heating Inside | Heating Outside |
|---|---|---|---|---|
| Dry bulb temperature, F | 78 | 95 | 72 | 0 |
| Wet bulb temperature, F | 65 | 78 | 55 | —1 |
| Effective temperature, F | 72 | 85 | 66 | .. |
| Dew point temperature, F | 58 | 72 | .. | .. |
| Heat Transfer Coefficient, Btu per sq ft per hr per F | | | | |
| Walls, 8 in. speed tile | | | | 0.36 |
| Gunite gables | | | | 0.80 |
| Roof (precast tile with white gravel and 1 in. thick cork insulation) | | | | 0.20 |
| Monitor glass (¼ in. coolite nonglare, 27 per cent solar radiation transmitted) | | | | 0.45 |
| Windows (⅛ in. coolite nonglare, 34 per cent solar radiation transmitted) | | | | 0.576 |
| Concrete | | | | 0.60 |
| Wood | | | | 0.75 |
| Sensible heat per occupant, Btu per hr | | | | 225 |
| Latent heat per occupant, Btu per hr | | | | 206 |
| Occupants—Center Shop (3 shifts) | | | | 15,000 |
| South Shop (3 shifts) | | | | 9,000 |

**Table 2—Heating design data and conditions**

| | Btu per Hr Loss Center Shop | South Shop |
|---|---|---|
| Roof | 22,750,000 | 14,650,000 |
| Walls | 3,100,000 | 3,046,750 |
| Windows | 2,120,000 | [illegible] |
| Gunite surface | 403 200 | 102,500 |
| Monitors | 13,370,000 | [illegible] |
| Door area | 169,700 | 119,450 |
| Door cracks | 591,000 | 638,000 |
| Door openings and closings | 3,900,000 | 1,755,000 |
| Window cracks | 9,000,000 | [illegible] |
| Infiltration through tile | 930,000 | [illegible] |
| Total infiltration | 14,421,000 | [illegible] |
| Outside air (15 per cent @ 0F) | 67,600,000 | 42,200,000 |
| Total @ 0F | 123,933,900 | 62,511,000 |
| Steam requirements, lb per hr | 124,000 | 63,000 |
| Same as above except outside air 45 F and 70 per cent relative humidity, lb per hr* | 113,000 | 67,800 |
| Power load, kilowatts | | |
| Motors | 6,983 | 6,315 |
| Lights | 2,528 | 1,170 |

*Window loss by radiation offsets additional outside air at 45 F. Time: 59 per cent heating, 32 per cent cooling, 9 per cent ventilation.

Note: Temperature under roof and monitors, 80.7 F (72 + 8.7).

The same system of piping, pumps, etc., is used. Each platform unit is equipped with its own heating or cooling coil, filter, fan, and distribution system. This system operates to take in outside or recirculated air in correct proportions as determined by the effective temperature control.

Condensing water is supplied by a cooling tower, water being pumped through the refrigerating and steam condensers arranged in series. Hot water for heating is secured by using exhaust steam and closed heaters. Both hot and cold water are circulated with the same

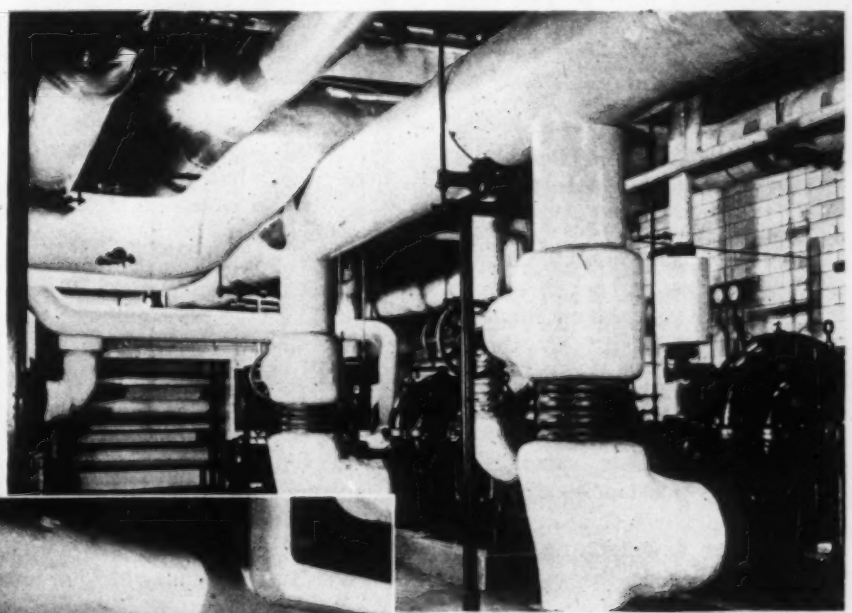
**ITS WAR RECORD has won acceptance for air conditioning in many types of industrial operations. In a large number of war plants, blackout construction, tremendous roof areas, big internal heat loads due to power and lighting and processing, high occupancies, etc., made air conditioning essential, as did the production rates and efficiencies required in the "battle of production". This experience with plant air conditioning, and the advantages of employing it as a production tool, are leading to its increasing use in peacetime industry . . . Much of the information secured during the war is just becoming generally available. The present article briefly describes the heating, ventilating, and air conditioning of the Wright Aeronautical plant at Lockland, and the tables summarize the design conditions as well as operating and maintenance charges.**

pumps through the same piping and, in many cases, through the same set of coils.

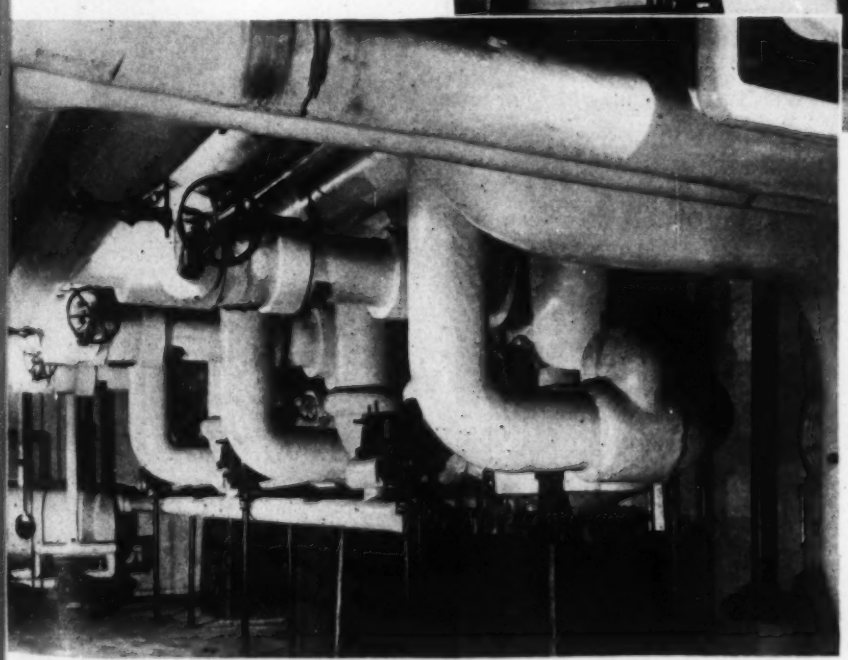
### Storage Effect Carries Excess Load

After the original plant was installed, a second building (1,295,835 sq ft under one roof), called the south shop, was designed with duplicate equipment for heating and cooling purposes. However, due to the restrictions on refrigerating compressors and critical materials, additional refrigerating capacity was never provided, although additional steam generating capacity was installed. Due to the inability to secure equipment and get the heating plant in this building in operation, it became necessary to tie-in this heating system to that of the center shop. In this manner, heat was provided from the same central source as that installed originally for the center shop. This tie-in permits the use of excess refrigerating capacity during light loads and as a result we were able to share refrigerating capacity and distribute it between these two buildings to provide comfort for the greatest number of employees.

Very satisfactory results were obtained during the summer months with this arrangement, due to the fact that the centrifugal water cooling equipment was operated 24 hr per day and seven days per week once the outside weather conditions required cooling. The tonnage (9301 tons) of refrigeration required to produce ideal conditions of 78 F dry bulb and 65 F wet bulb indoors when the outdoor temperature is 95 F dry bulb and 78 F wet bulb far exceeds the actual tonnage produced by the centrifugal water cooling equipment (6000 tons). The conditions were comfortable due to the large storage effect in the objects within these spaces, such as



The hot and chilled water circulating pumps for the center and south shops. The same system of piping, pumps, etc., is used for cooling and heating



These are the hot water heaters for supplying the south shop

**Table 3—Cooling design data and conditions**

| | Btu per Hr Loss | |
|---|---|---|
| | Center Shop | South Shop |
| Temperature difference and sun effect | 8,519,600 | 731,697 |
| Occupants, sensible.. | 3,375,000 | 787,500 |
| Outside air, sensible. | 8,180,000 | 5,310,000 |
| Power ..... | 23,800,000 | 21,600,000 |
| Lights ..... | 8,630,000 | 3,996,720 |
| Total sensible heat... | 52,504,600 | 32,427,917 |
| Outside air, latent... | 14,180,000 | 8,800,000 |
| Occupants, latent..... | 3,090,000 | 612,500 |
| Total latent heat..... | 17,270,000 | 9,412,500 |
| Total Btu per hr..... | 69,774,600 | 41,838,417 |
| Refrigeration required, tons ..... | 5,815 | 3,486 |

**Table 4—Power and maintenance cost, Center Shop**

| | Cooling | | | | Heating | | | | Ventilation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr |
| Assembly | 1,350 | 504,500 | 282 | 538,390 | 1,350 | 504,500 | 281 | 990,150 | 1,350 | 504,500 | 281 | 169,1 |
| Machine shop | 71,950 | 1,697,375 | 814 | 1,595,329 | 71,950 | 1,697,375 | 813 | 2,933,547 | 71,950 | 1,697,375 | 813 | 501,3 |
| Plating department | 52,500 | 87,500 | 40 | 71,117 | 52,500 | 87,500 | 40 | 130,790 | 52,500 | 875,000 | 40 | 22,3 |
| Mezzanine | 49,000 | 61,000 | 55 | 84,174 | 49,000 | 61,000 | 55 | 101,707 | 49,000 | 61,000 | 55 | 26,4 |
| Administration | 76,100 | 92,500 | 78 | 106,626 | 76,100 | 92,500 | 78 | 146,538 | 76,100 | 92,500 | 78 | 33,5 |
| Warehouse | 500 | 50,000 | 30 | 39,428 | 500 | 50,000 | 30 | 72,512 | 500 | 50,000 | 30 | 12,3 |
| Basement | 40,000 | 77,000 | 57 | 102,009 | 243,000 | 307,500 | 89 | 513,047 | 243,000 | 307,500 | 89 | 149,4 |
| Heat treat | ..... | ..... | .... | ..... | 208,000 | 205,000 | 132 | 520,097 | 208,000 | 205,000 | 132 | 104,4 |
| T. C. control room | ..... | ..... | .... | ..... | ..... | 67,500 | 27 | 76,972 | ..... | 67,500 | 27 | 13,1 |
| Total | 291,400 | 2,569,875 | 1,356 | 2,537,073 | 702,400 | 3,072,875 | 1,545 | 5,485,360 | 702,400 | 3,860,375 | 1,545 | 1,032,3 |
| Hours of operation | | 2,778 | | | | 5,112 | | | | 888 | | |
| Total power cost | | $17,760 | | | | $38,384 | | | | $7,226 | | |
| | | Maintenance Cost (Labor and Material)* | | | | | | | | | | |
| Platform units | | $ 1,245 | | | | $ 2,678 | | | | $ 450 | | |
| Fans, misc. exhaust and supply | | 648 | | | | 1,393 | | | | 228 | | |
| Fan rooms, cafeteria and adm | | 232 | | | | 499 | | | | 120 | | |
| Climate changers | | 154 | | | | 332 | | | | .... | | |
| Radiators | | .... | | | | 368 | | | | ..... | | |
| Pumps | | .... | | | | 715 | | | | .... | | |
| Total | | $ 2,279 | | | | $ 5,985 | | | | $ 798 | | |

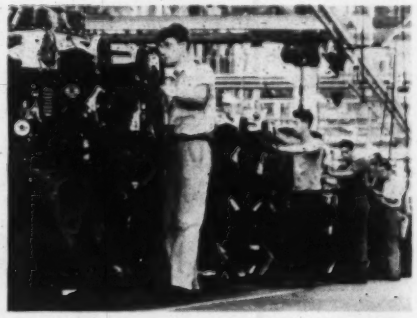
*Additional maintenance included under operating servicemen in air conditioning department.

the machine tools, the large mass of parts being machined and in finished machine parts, and in the building structure itself. Further, the peak outside load due to sun effect and outside wet bulb temperature occurs when the second shift started to work at 4:00 p.m., during which period the internal heat load due to power used on machine tools and the people load was somewhat reduced.

### Air Conditioning Cost Is 1½ Cents per Man-Hour

The above briefly describes the Lockland air conditioning installation. What does it cost to operate such a system? Is the maintenance cost excessive? What is the cost of operation per man-hour? Which factors give the greatest amount of trouble? What is the ratio of fixed charges to operating costs? What is the relative cost of heating versus air conditioning?

The costs and factors involved are summarized in the accompanying tables.* They include such costs



as (a) power for operation of fans, (b) maintenance of central air conditioning equipment, (c) feedwater treatment, (d) steam and power costs to operate pumps, refrigerating equipment, and (e) operating cost.

Initial cost of all equipment is included and itemized. The fixed charges are determined for each operating condition and assumed to be 20 per cent of the initial investment. This is considered to be extremely liberal and includes depreciation, interest, taxes, and insurance.

Operating costs are broken down so that one may get some conception of the nature and extent of the charges involved. Operating as well as maintenance charges for the year (1944) are actual and as reported by the budget division.

Summary sheets are included in which comparative costs are included for both the center and south shops under all conditions of operation. The cost of air conditioning these buildings is approximately 1.5c per man-hour.

| | |
|---|---|
| Installation cost per sq ft | $1.00 |
| Installation cost per cu ft | 0.035 |
| Operating and fixed charges per sq ft per year | 0.34 |
| Operating and fixed charges per cu ft per year | 0.013 |
| Operating and fixed charges per man-hour | 0.015 |

Credit for the design must be given to Albert Kahn Associated Architects and Engineers. Frank A. McBride Co., mechanical contractors, installed the system.

*Editor's note: Five of the total of 10 tables appear this month. The rest will be published in the next issue.

**Table 5—Power and maintenance cost, South Shop**

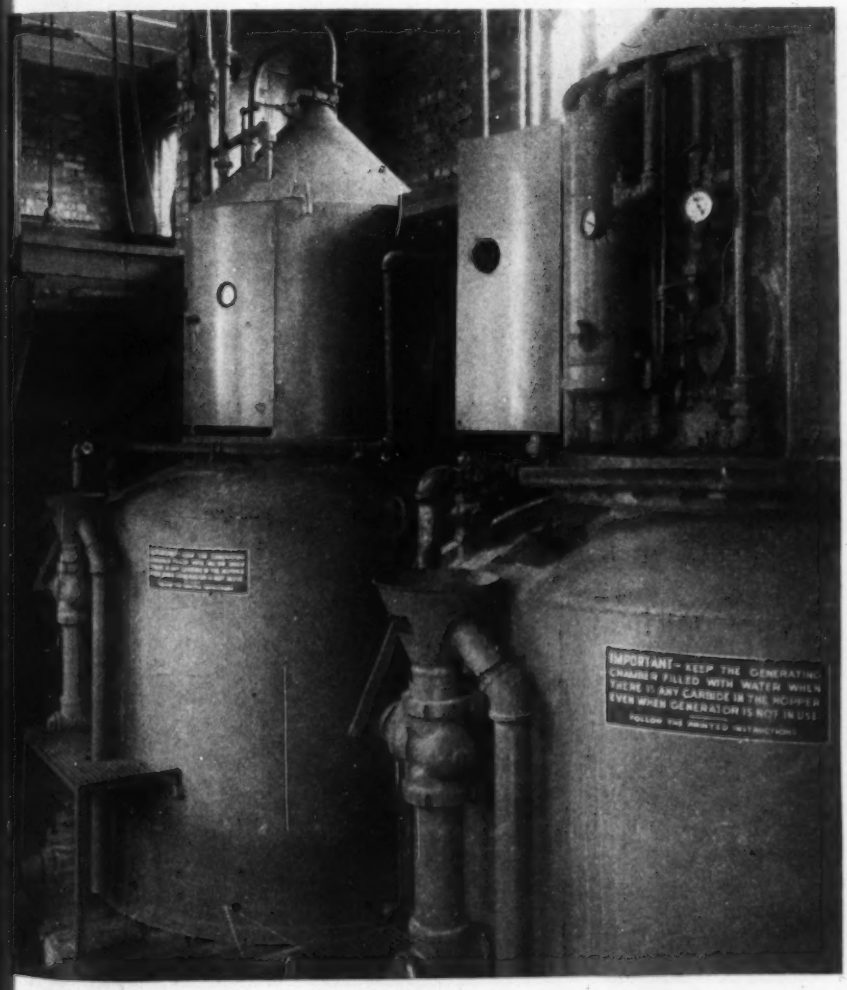
| | Cooling | | | | Heating | | | | Ventilation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr | Exhaust Cfm | Supply Cfm | Req'd. Hp | Kwhr |
| Machine shop | 882,750 | 1,431,250 | 362 | 1,004,245 | 882,750 | 1,431,250 | 731 | 1,846,901 | 882,750 | 1,431,250 | 731 | 315,5 |
| Office and aud | 105,735 | 78,500 | 78 | 132,427 | 106,235 | 78,000 | 78 | 243,558 | 106,235 | 78,000 | 78 | 41,6 |
| Basement | ..... | ..... | .... | ..... | 457,000 | 641,000 | 405 | 1,380,959 | 457,000 | 641,000 | 405 | 236,0 |
| Cafeteria | ..... | ..... | .... | ..... | 50,000 | 50,000 | 50 | 130,278 | 50,000 | 50,000 | 50 | 21,8 |
| Heat treat | ..... | ..... | .... | ..... | 120,000 | 140,000 | 62 | 294,278 | 120,000 | 140,000 | 62 | 108,5 |
| Nitride | ..... | ..... | .... | ..... | 80,000 | 70,000 | 33 | 153,627 | 80,000 | 70,000 | 33 | 48,1 |
| Total | 988,485 | 1,509,750 | 440 | 1,136,672 | 1,695,985 | 2,410,250 | 1,359 | 4,049,601 | 1,695,985 | 2,410,250 | 1,359 | 771,7 |
| Hours of operation | | 2,778 | | | | 5,112 | | | | 888 | | |
| Total power cost | | $7,957 | | | | $28,347 | | | | $5,402 | | |
| | | Maintenance Cost (Labor and Material)* | | | | | | | | | | |
| Fan rooms | | $ 295 | | | | $ 632 | | | | $ 107 | | |
| Fans, misc. exhaust and supply | | 409 | | | | 878 | | | | 136 | | |
| Platform units | | 360 | | | | 771 | | | | 113 | | |
| Pumps | | .... | | | | 490 | | | | .... | | |
| Radiators and unit heaters | | .... | | | | 304 | | | | .... | | |
| Total | | $1,064 | | | | $ 3,075 | | | | $ 356 | | |

*Additional maintenance included under operating servicemen in the Air Conditioning Department.

# PIPING for Distribution of Oxygen and Acetylene Cuts Manufacturing Costs

**By M. W. HIPPE**

**WHERE OXYGEN and acetylene are used at various points in a plant for processes such as welding, brazing, soldering, heating applications, etc., distribution from a central point through piping systems can often lead to sizable savings in production costs. Mr. Hippe, service engineer, Linde Air Products Co., describes here the installation at Modine Mfg. Co., where—on the basis of 12 months' experience—it is indicated that the method is fully justified from the standpoint of capital outlay and will reward the company in its long range operations. . . . Piping systems for this service may range in size from a few hundred feet and a limited number of station outlets at a small manufacturing plant to layouts involving miles of piping and hundreds of station outlets. . . . Piping is industry's most important transportation system**


IMPORTANT—KEEP THE GENERATING CHAMBER FILLED WITH WATER WHEN THERE IS ANY CARBIDE IN THE HOPPER EVEN WHEN GENERATOR IS NOT IN USE

**View of the two generators, showing water service lines ending just above the filling funnels, and the vents and acetylene service lines**

MANY OF THE advantages to be gained by piping the acetylene and oxygen used in industrial plants from central sources of supply have been recognized for a number of years. However, a large increase in the use of flame processes consuming acetylene and oxygen during the war greatly accelerated the installation of these piping systems, which may range in size from a few hundred feet of pipe and a limited number of station outlets in smaller manufacturing plants to layouts involving miles of piping and hundreds of station outlets in steel mills and shipyards.

The Modine Mfg. Co., Racine, Wis., a large producer of unit heaters, nonferrous convectors, extended surface air conditioning coils, and automotive radiators, uses large volumes of acetylene and oxygen for welding, brazing, soldering, and heating applications. A brief study of the economics involved indicated that sizable savings were possible if pipe lines were installed to supply acetylene and oxygen to the many use points along the production lines. With this established, a complete survey was made to determine what percentage of the total consumption could be served by pipe line, the location of use points, and the hourly demand rate at each use point.

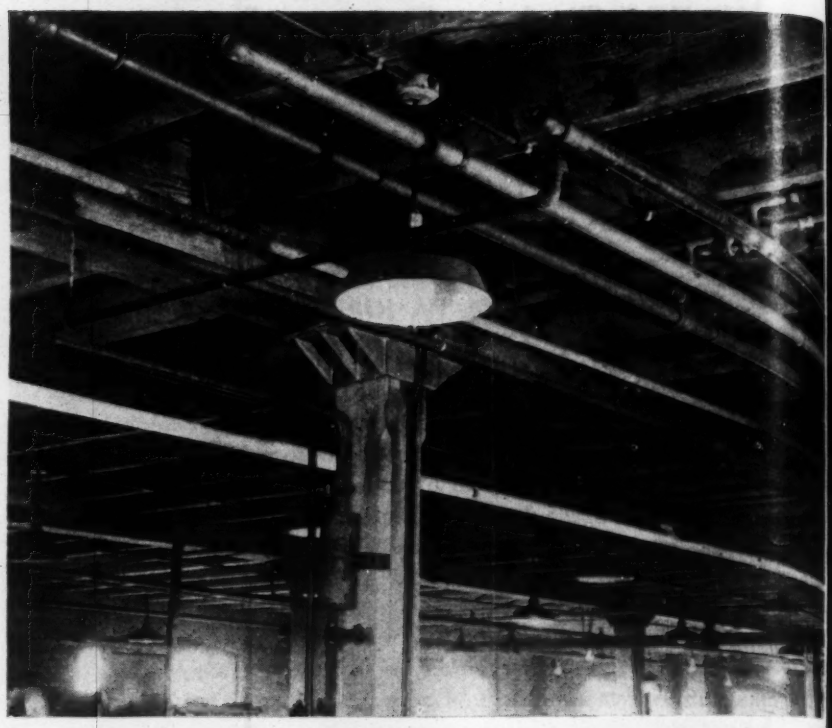
### Main Runs Kept to Minimum

The locations for the oxygen unit and acetylene generator buildings were then considered in laying out the line. These were placed so as to keep the main runs of pipe to the minimum and sufficiently separated from one another and other buildings to comply with safety requirements. The routing of the piping and the number and location of the station outlets, as well as the hourly demand rate of all the stations, were then determined. From these data, pipe sizes were calculated and plans were drawn for the systems. The possibility of increased consumption was considered and allowances were made in pipe sizes for carrying the estimated future demand. A number of branch connections were welded to the mains and capped, permitting re-

location of installed laterals and the addition of others if required later.

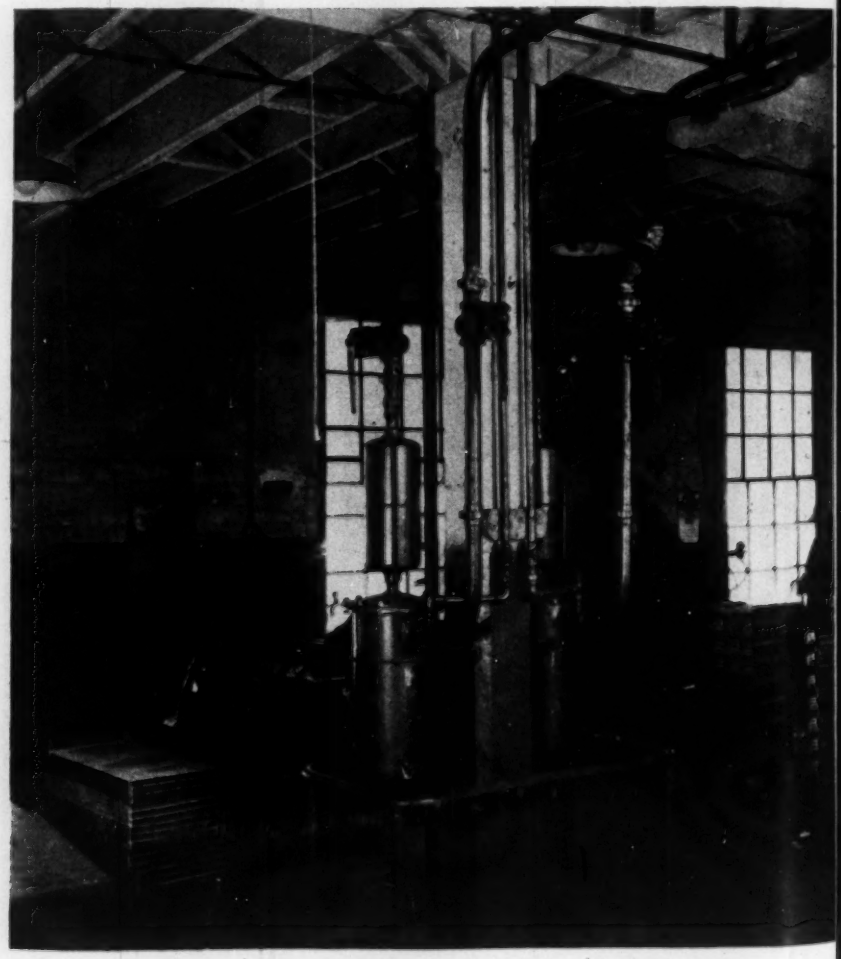
The main lines are of 1½ in. size, standard weight black iron pipe being used for acetylene and extra heavy for oxygen. All laterals and drops are ¾ in. pipe, standard and extra heavy pipe being used as indicated before. The 1½ in. lines are run underground from the supply units to the main building, entering this building in the basement. From the basement, risers extend to the ceiling of the third floor, where the main branches extend in two directions. Stubs with valves and capped nipples were installed near the ceilings on both the first and second floors for future expansion. Provision was made for four stations on the fourth floor by installing vertical extensions from the main on the third floor. These vertical extensions are attached to the building columns with brackets and, are held close to the columns, thus requiring a minimum of space. All stations have four outlets for each gas, so that four operators can work from each station.

The building for the acetylene generator is rather unique in design, as it is constructed on three levels; this greatly facilitates the handling of calcium carbide and sludge. Piping in the generator house consists of water service, heating coils, and necessary connections to tie the service outlet from each generator to a common header. There are also vent lines from the



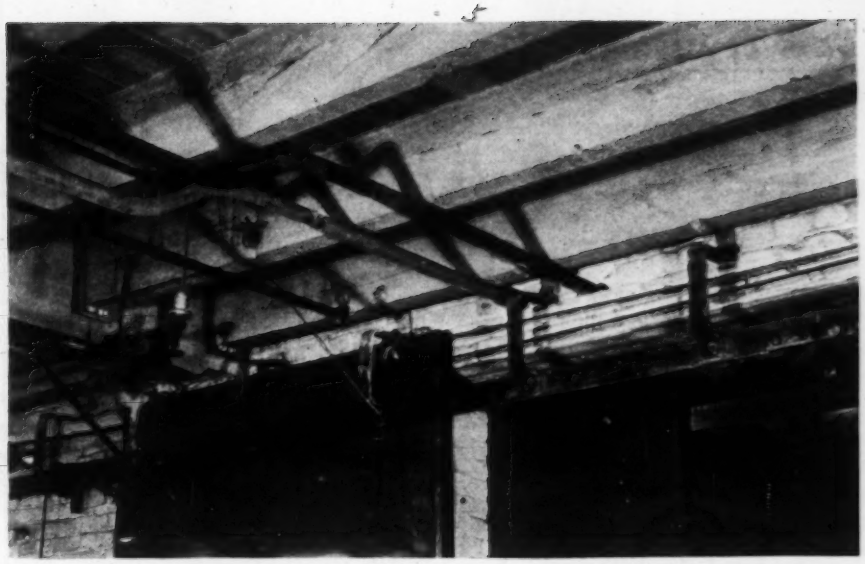
**End of one of the two main branches. Acetylene line is on right side with extension of ¾ in. pipe to drip pot on column**

**Hydraulic backpressure valves are installed on third floor where main acetylene line branches in. One valve is used for each branch with inlets shown at the top**

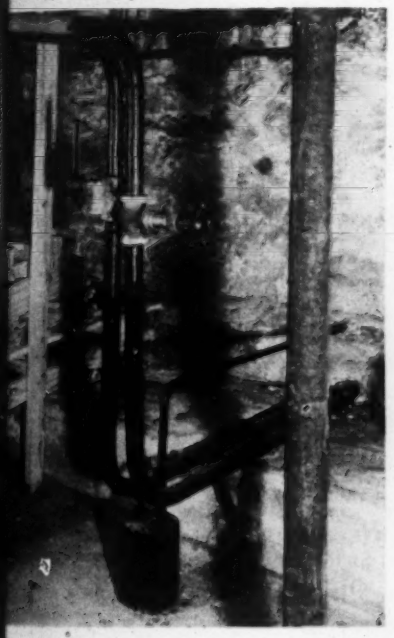


**Risers are protected with a heavy guard to prevent damage from material handling trucks on the first and the second floors of the factory**

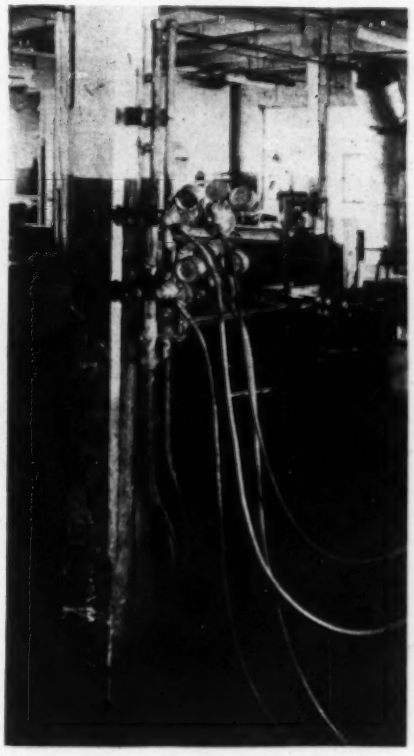
iser extending from basement to hird floor. Stubs are welded to the isers, with valves and closed end ipples, for future use on two floors



Offsets for elevation changes in main branch lines were easily and quickly made by heating with the welding blowpipe and bending



Lines entering basement of main uilding. Drip pot is used only on he acetylene line. Drain from drip ot is run to the outside of building



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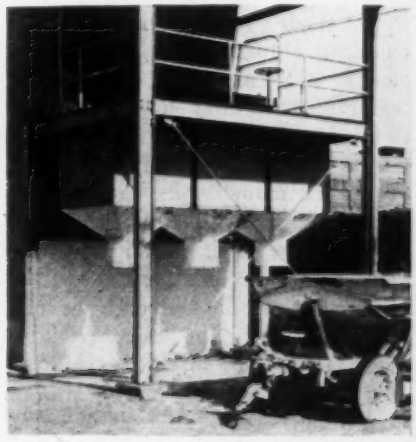
This view shows station outlets where the lines are brought up through the floor rather than down from the ceiling



End view of generator house, showing the three receiving tanks for sludge and the trailer for sludge disposal.

elief valves on the generator and he hydraulic backpressure valves. Pipe is also used to good advantage or guard rails inside the building, n the platform above the sludge anks, and at the stairway leading p to the loading dock. Oxyacetyene welding of these guard rails ives sturdy construction and neat ppearance.

It is not intended to go into detail here on specifications for installing piping systems of this nature. Approved specifications for this purpose can be obtained from most suppliers of acetylene and oxygen on request, and it is suggested that this be done whenever such systems are contemplated. This also applies to plans and specifications for buildings for acetylene generators and is of the utmost importance in the latter case because of insurance and safety regulations.

### Affects Production Costs

Modine is of the opinion that the rate of savings and economies effected in acetylene and oxygen costs over an initial period of 12 months indicates that the new method is fully justified from the standpoint of capital outlay and will reward the company in its long range operations.

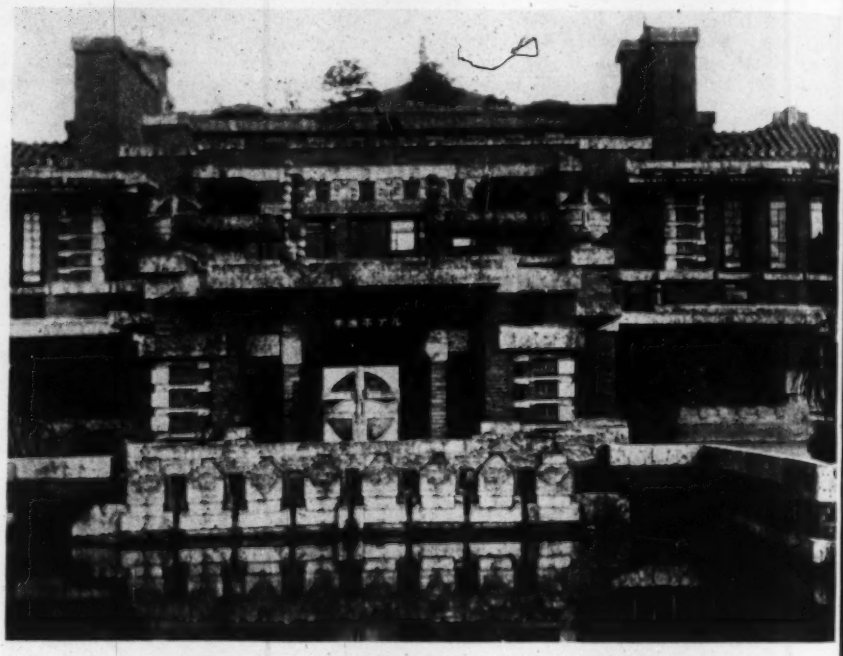
Now that the war is over and production costs are being studied more closely, it appears logical that all firms using these gases will want to make a study of this economical system of acetylene and oxygen distribution.

# Here Are PRACTICAL TIPS on Radiant Heating

*In this regular feature, informal comment on heating, piping, and air conditioning matters is given by Samuel R. Lewis, consulting mechanical engineer, and a member of HPAC's board of consulting and contributing editors*

FRANK LLOYD WRIGHT, the international architect, says that he became interested in radiant heating after noting that the warm water pipes in the walls serving lavatories and baths in the Imperial hotel in Tokyo heated the bathrooms. Certainly, many rooms in buildings have always been heated by large areas in floors and walls without anyone particularly realizing it.

Steam or hot water are by no means the only carriers of heat to large, moderately warm, heat transmitting surfaces. During the financially wild 1920's, skyscraper apartment buildings flashed up like mushrooms overnight. Fortunate were those that employed free-standing chimneys for their boiler plants. Chimneys running up through multistory buildings tend to overheat the rooms that they adjoin, and expansion and contraction of the chimney walls interpose a continual redecorating problem. One 35 story hotel has 35 otherwise attractive bedrooms, one above the other, that are unsalable [in normal times] because of uncontrollable overheating due to the warm wall of the great chimney on one side of each room.



**Frank Lloyd Wright became interested in radiant heating when he noticed that the service water piping in the walls warmed the bathrooms in Tokyo's Imperial hotel**

### Warm Air Radiant Heating

There are many homes that are reasonably well heated by warm air circulated through small tile ducts under the floor. One successful installation in a large living room that is exposed to the weather on the east, west, and north has a masonry warm air supply duct below the floor along the west wall, communicating through transverse tile ducts with a similar masonry return duct below the floor along the east wall. A fan receives the air from the return air duct, forces it around a furnace, and then into the supply duct. The warm air does not enter the living room at all.

This scheme for radiant heating is as old as houses and fire, going back to prehistoric times when products of combustion were drawn through underfloor ducts.

Most modern applications of radiant heating are successful, though there are a few failures. Progress may be gained not only by observation of successful installations; we learn also from experience with the unfortunate ones.

An optimistic and very large heating system in one residence had 1¼ in. pipes about 2 ft apart, imbedded in the concrete floor. There were 2 in. headers at the ends of the 1¼ in. transverse pipes. The underfloor heating was installed for a wing of the one-story building without consideration of the partitions that would be built on the floor to form five large bedrooms and their adjacent bathrooms. No attention was paid to the differences in exposed wall and glass areas in the various rooms.

Steam was circulated through the pipes with an electric vacuum pump designed to insure a low absolute pressure of the vapor to permit a steam temperature in mild weather as low as 160 deg.

This plant is a failure. It has demonstrated that, with underfloor heating, to accomplish the transmission through many tons of concrete, the time lag is too great. Enough heat to bring comfort in the early morning, even though the

steam is shut off entirely by eight o'clock, renders some of the rooms too warm on most days until mid-afternoon. Those rooms nearest the boiler and those with the least exposure are overheated, while the more distant rooms or those with unusually large exposure are uninhabitable. Correction of this situation is a major operation.

### A Recently Designed Job

A recently designed radiant heating system for a large country home is arranged as follows: There is an oil burning hot water heater. The radiant piping for each room is of the serpentine type and is proportional in surface area to the individual room heat loss. The pipes are small in diameter but are so spaced to cover most of the ceiling. They were welded and tested on the floor in each room, then hoisted against the ceiling below adequate insulation. This insulation is used to prevent uncontrollable overheating of the rooms above. The metal lath for the ceiling plaster was wired to the pipe coils, and the brown coat was forced through the lath and around the pipes. In some rooms it was possible to install plaster above the pipes before the rough floor of the rooms above was laid, and then to apply the insulation above this plaster.

The radiant heat transmitter in each room is served by risers from basement mains and risers to attic mains, with accessible valves in the branches, so that the rate of water flow to each room can be adjusted, and so that the water can be shut off and drained if desired. The heat transmitters were pitched so that all original air and all entrained air would vent to a trapped header above the overhead main. Separate mains and separate electric water circulating pumps serve the principal zones as follows:

(a) First story master living quarters.
(b) Second story principal bedrooms and bathrooms.
(c) Guestroom wing.
(d) Servants' wing.

### Outdoor-Indoor Control

Each of these systems has a separate thermostatically controlled, water-mixing valve, each adjusted continuously by an outdoor-indoor control, so that the water temperature in the radiant coils in each zone varies as needed from 100 per cent hot, coming from the boiler, to 100 per cent recirculation, depending on the weather outside and on the desired temperature inside. This is a successful plant. Its design includes the prescriptions that avoid most of the so-far-discovered illnesses of radiant heating.

Radiant heating does not eliminate the necessity for the application of the principles of design and control that have been developed slowly over many years by experience with other methods of heat transmission.

# FORD HAS BIG POSTWAR EXPANSION PROGRAM

## *Southeast Assembly Plant Follows Overall Plan*

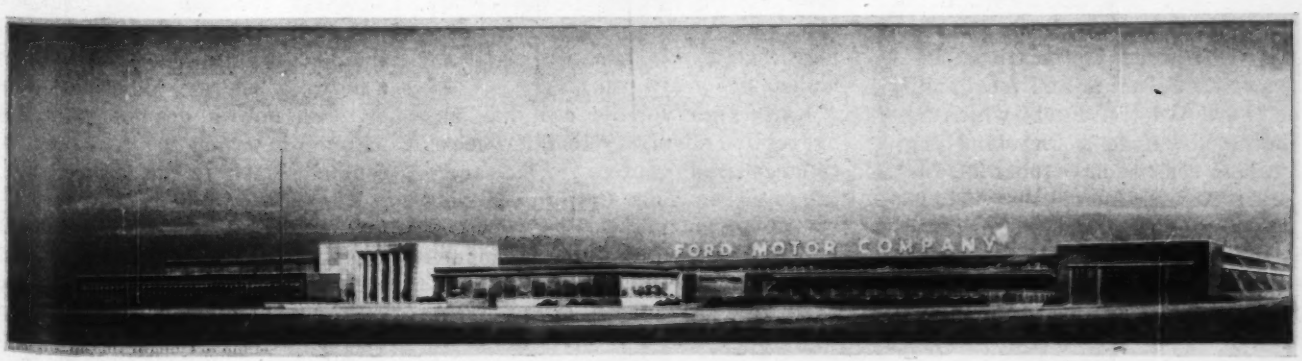
ANOTHER ADDITION to the huge postwar expansion program of the Ford Motor Co. is an assembly plant at Atlanta, Ga., which will add a peak of 350 new cars and trucks a day to dealer and public supply in the expanding southeast market. The overall plan follows the same general pattern evolved by Albert Kahn Associated Architects & Engineers, Inc., on other automotive projects designed for Ford.

Principal structures are an assembly building, office building connecting with the main plant, oil house, and boiler house. All are steel framework buildings, with steel sash and brick, gunite and limestone walls, and are one-story structures of irregular height with no basement area. Glass block is also used in a higher section of the office building above the general office area.

Mezzanine stairways lead to work stations on the production floor. To the north is the boiler house with two combination gas and oil fired boilers supplying 40,000 lb per hr of steam for heat and process work. Low stacks with induced draft fans are provided for the boilers in order to clear the airway lanes from the airport some distance away. Provision is made in the original design for a third boiler, and a third air compressor may likewise be added to the two specified in the original installation. There is a separate oil house and oil, water, and paint storage tanks with protecting dykes.

Ventilating fans are contained in fan rooms on the flat, metal deck monitorless roof of the main plant.

**New Ford assembly plant in Atlanta**



# A SMOKE ELIMINATION Program THAT WORKS

IT HAS BEEN shown in these articles outlining the methods employed by the city of St. Louis for the elimination of smoke that it is necessary to attack the problem at the source. The fundamentals of any smoke program are the use of equipment that can burn the available fuel smokelessly, or the use of a fuel that will not smoke; these principles are self-apparent and basic. There may exist, in various communities, however, opposition to a program based upon these principles. This opposition may be satisfied with results materially less than could be obtained had the fundamental tenets enunciated above been adhered to. Whether a community will be satisfied with less is for the citizens of that community to decide. But the ultimate goal will never be achieved until the precepts established in St. Louis are accepted.

It has been stated by those who oppose the St. Louis program that if all communities accepted this method, there would be insufficient low volatile coal to satisfy the demands. This argument, of course, is fallacious, and if it were true and carried to its logical conclusion, new discoveries, devices, or principles would not be used until there was a supply sufficient to meet the demand. The beneficial effects of penicillin would have been lost for years, and the sulfa drugs could not have been used in the treatment of many cases if we awaited the time until the supplies were adequate.

There are ample reserves at present of low volatile fuel. It is estimated in a paper identified as I. C. No. 7261, printed by the U. S. Department of Interior, November 1943, that the present low volatile fuels, if consumed at the same rate as in 1941, would last 366 years. The field itself, according to the same source of information, is only 5 per cent exhausted. W. E. E. Koepler, secretary of the Pocahontas Operators Association, in a paper on Selection and Availability of Low Volatile Fuels which was delivered before a Cleveland engineering society on October 29, 1945, said: "It is estimated that 177,700,000 tons of low and medium volatile fuels are available each year." This includes coke, briquettes, etc. He further argued that over 50 per cent of this tonnage is fuel especially prepared for the domestic market. If this is true, there is then available approximately 88,000,000 tons for domestic consumers. He further stated that the retail domestic market of the bituminous coal industry is estimated at about 20 per cent of the total; this would result in the domestic trade consuming approximately 120,000,000 tons per year. This tonnage includes a large proportion of stoker coal. Under these conditions it would appear that there is sufficient low volatile fuel for all, and if there is not, high volatile fuel should be processed.

The increased use of mechanical fuel burning equipment affords a very definite market for high volatile fuel, as well as a permanent one. This is substantiated by reports of the U. S. Department of Commerce, bureau of census, on factory sales of mechanical stokers.

### Smoke Elimination Demands Better Fuels and Equipment

Smoke elimination is going to be ever demanding—and seeking—fuels and equipment more adaptable to its requirements. Ordinances for the elimination of smoke will become increasingly severe as time goes on. What was considered severe five years ago will be too lenient five years hence.

Raw, high volatile coal has an aggressive adversary in this desire of large urban centers for a cleaner atmosphere. This desire was not vociferous during the long period of the war, but was lying dormant. It has again become vocal. To meet this need a variety of products must be available to meet the individual tastes and appetites of the consumers. No one solution will be satisfactory. Available equipment, such as stokers, must be improved to meet the meticulous requirements of the public and enforcement officers. Processed fuels having undesirable attributes must be investigated and these characteristics minimized or eliminated. High volatile fuel must be processed and made into a desirable fuel for hand firing.

### Coal Is Major Source of Energy and Smoke

It is unreasonable to expect every consumer to scrap his present equipment in order to use solid, high volatile fuel. If this is required you will find him dissatisfied and seeking other sources of energy —such as gas or oil.

Coal has been the major source of energy and smoke in the United States for many years. It is estimated that approximately 45 per cent of the total energy supplied by mineral fuels and water power comes from coal. It is further estimated that the bituminous coal reserves in the United States are such that they will last over 2000 years. The total reserves of all coals will last in excess of 3000 years. Coal should occupy the major position as a source of energy. Whether it does or does not is dependent on the manner in which the coal industry conducts itself in the future.

The industrial market in all probability will continue to be an outlet for coal, provided there is no encroachment on this market by the development of ways and means to utilize atomic energy. However,

leading scientists recently testifying before a Senate committee stated that the production of plutonium will reach 10 tons a year in 10 years; this would permit the generation of power equivalent to the total power developed in the United States in the year 1941. Atomic energy, therefore, may be a reality in marine and stationary practice in the near future. The position of the railroads and domestic market with reference to coal is also questionable.

### Coal Has Many Competitors

Coal has many competitors, most formidable among them being gas, oil, diesel locomotives, gas turbines, atomic energy—all of which contribute materially to the elimination of smoke, and because of this their use will be more widespread.

*Gas*—The gas industry has embarked on a program of aggressive action to improve the economics of its business and to meet the competition of other fuels in the postwar period. All in all, the indications are that the industry is developing an aggressive attitude toward any indicated form of competition in the postwar period by not only keeping alive a market already established, but by bettering its product and imparting that information to the public which it serves.

Ralph Sherman, in an article on Future Fuels, states that "the future market for manufactured gas will continue to be in the domestic field, including cooking, water heating, refrigeration, comfort heating, and cooling. Manufactured gas must naturally cost more per unit than the solid fuel from which it is made. Because of its advantages of cleanliness, ease of control, relatively low cost of the equipment for its utilization, and the fact no storage facilities are required, gas can command a higher price."

The gas industry may also be aided by better distribution; some of the present oil pipe lines may be used for the distribution of natural gas. This opens large additional markets now served almost entirely by coal. The increased use of natural gas will release additional tonnages of low volatile fuel for hand firing. One may say, "Oh, but the natural gas reserves of this country can only last 30 to 35 years." This may be true, but 35 years is a long time to be hungry.

*Oil*—Oil has been an active competitor of coal in domestic heating as well as in the industrial and transportation fields. No doubt the leaders of the oil industry have plans similar to those of the gas industry. Bulletin No. 96 of the Oil Heat Institute of America, published January 4, 1946, calls attention to a prediction estimating the sale of oil burners at approximately 500,000 a year for the next five years, and to evidence substantiating this prediction. A. C. Fieldner, chief of the fuels and explosive service, Bureau of Mines, stated in I. C. 7261, U. S. Department of the Interior, the following: "Since 1923 the use of fuel oil has spread to various industries, especially for operations requiring flexibility of heating, accurate control of temperature, and freedom from ash. The most important recent trend before we entered the war was the ever accelerating gain of oil heating for homes, apartments, and office buildings. The sale of heating and range oils increased from 25,000,000 barrels in 1926 to 168,000,000 barrels in 1941. This quantity of oil is equivalent to 38,000,000 tons, or 70 per cent of the 1941 production of anthracite coal. In all its uses the consumption of fuel oil sold in 1941 was equivalent to about 126,000,000 tons of coal, slightly more than one-fifth of the total production of all ranks of coal for the same year."

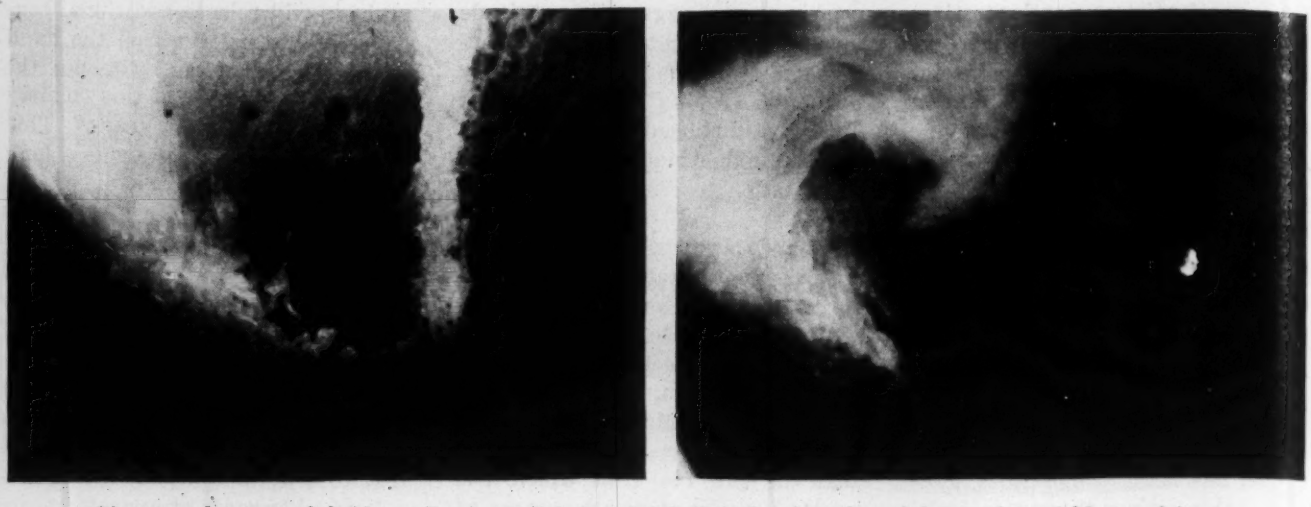
*Diesels*—The diesel locomotive has definitely proved its worth in switching services and is turning in an excellent performance in main line service. Diesels have made a material contribution to smoke elimination, and will continue to do so.

One may also expect the increased use of diesels in the generation of power in small isolated steam plants. Costs will be reasonable and efficiency high, so there too one may expect inroads to be made upon the sale of coal.

*Gas Turbines*—Gas turbines are not new. They are over 100 years old, and recently they have made

## *Smoke Elimination Will Seek Fuels and Equipment More Adaptable to Its Needs, Says Raymond R. Tucker*

**FUNDAMENTAL to any smoke abatement program is the use of equipment that can burn available fuel smokelessly, or the use of fuel that will not smoke, says Professor Tucker in introducing his discussion this month of "the battle of the fuels," and research on coal—our major source of energy and smoke. The desire to reduce "atmospheric sewage" (as it has been called by some), dormant during the war, has again become vocal, and is going to be ever demanding and seeking fuels and equipment more adaptable to its requirements, according to the author. . . . Professor Tucker is well qualified to write on smoke elimination, for he has been intimately concerned with the program in St. Louis. Now head of the department of mechanical engineering at Washington University in that city, he was smoke commissioner of St. Louis from 1937 to 1942. In addition to many talks on smoke elimination before various groups in St. Louis, he has also discussed the program at engineering meetings in cities where it is hoped to inaugurate similar projects. . . . Previous articles of this series were published in the September, October-November, and December 1945, and the January 1946 issues of this magazine.**



**Photographs toward bridgewall of small industrial boiler showing the mixing action of blower driven jets. When jets are off (left), flames rise in stratified streams out of fuel bed. With jets on (right), flames are whirled into space otherwise unused. These pictures are shown through the courtesy of Battelle Memorial Institute, where work is being carried on for Bituminous Coal Research, Inc.**

great strides. Many of these units have been built and are in operation. When the metals developed during the war capable of withstanding higher temperatures are available, their efficiency may be increased to approximately 30 per cent. At present, experiments are being conducted on the use of gas turbines as a source of power for locomotives and for marine service. The gas turbine also lends itself for use in stationary power plant work. It is relatively simple compared to a steam plant, and can be used where a source of water or solid fuel is not readily available.

Gas, oil, diesels, gas turbines, low volatile fuel, and atomic energy contain all the essential elements the public desires for smoke elimination. This is the handwriting on the wall which the coal interests must interpret.

### Research on Coal Under Way

The bituminous coal operators initiated a small research program in 1935 and renewed their efforts in 1943. However, a greatly enlarged program involving the expenditure of $500,000 a year is now under way. From information available, this includes research projects on mining and preparation methods; on technology of coal and ash; on improvement of hand fired furnaces and stoves, with the particular objective of producing smokeless operation; on the developing of automatic residential stokers; and on improved equipment for firing coal under steam boilers. Further work is being done on the complete gasification of coal and the application of coal to metallurgical and other processes of heating furnaces. The railroads also are coming in for their share of this development work. An attempt is being made to improve the motive power for this type of consumption.

So one may readily see that the coal operators have awakened. The approach to the solution of their problem by means of research is sound, and should produce results. They should not expect miracles to happen at once because it is only the exceptional research program that produces results overnight; as a rule the objectives are attained only after long, hard work.

Reports indicate that steady progress is being made in the development of the hand fired stove and furnace. No doubt marked improvement will be made in the burning characteristics as well as the operational features of the stoker. Research work on coal is not confined to any one institute. Various approaches are being made to this problem and from this intensive investigation one may expect encouraging developments. Even the state of Illinois has recognized the need of development and improvement in coal utilization, and has recently appropriated funds for research programs. These funds have even been allotted to private corporations when the work of these corporations is directed toward the improvement of the burning properties of their coal. The University of Illinois is carrying on a separate program which has as its objective the production of a low volatile fuel from Illinois coal. These are but a few of the many programs in progress at the present time.

It is encouraging to those interested in the elimination of smoke that the leaders of the coal industry are not going to be lulled into a feeling of complacency with statements that are made regarding the reserves of gas and oil. These statements may be true, but statements of a similar character have been made in the past and subsequently new oil and gas reserves have been uncovered. Coal, if it desires to survive, must take an aggressive attitude in preparing acceptable fuels for ultimate consumption, for the mere possession of a fuel does not necessarily mean that it will be utilized.

## SIMPLIFIED PRACTICE FOR COPPER TUBE AND PIPE

A proposed Simplified Practice Recommendation for Copper Water Tube and Copper and Brass Pipe has been submitted to producers, distributors, and users for comment or acceptance, or both, according to an announcement of the division of simplified practice of the National Bureau of Standards, Washington 25, D. C.

The proposed recommendation covers copper water tube and copper and brass pipe intended for plumbing uses. Its purpose is to establish a simplified list of types and sizes.

"THE COIL SHALL BE NOT LESS THAN

# SIX ROWS DEEP"

**THAT'S a statement often found in air conditioning specifications on jobs with high latent loads, and it better be checked by means of the psychrometric chart if you're going to guarantee the inside conditions maintained. Mr. Sampson, district manager, air conditioning division, Westinghouse Electric Corp., discusses the calculations for an air conditioned dining room in a small hotel, shows why it was necessary to re-figure the original design and to change the guarantee figures.**

By Will D. Sampson

THE COIL SHALL be not less than six rows deep in the direction of air flow and the face velocity shall not exceed four hundred and fifty (450) feet per minute." All of us have read that statement in a specification at one time or another. It might be a theater installation or a hotel dining room or it could be a bedroom in the tropics. At any rate, it indicates a job with a high latent load.

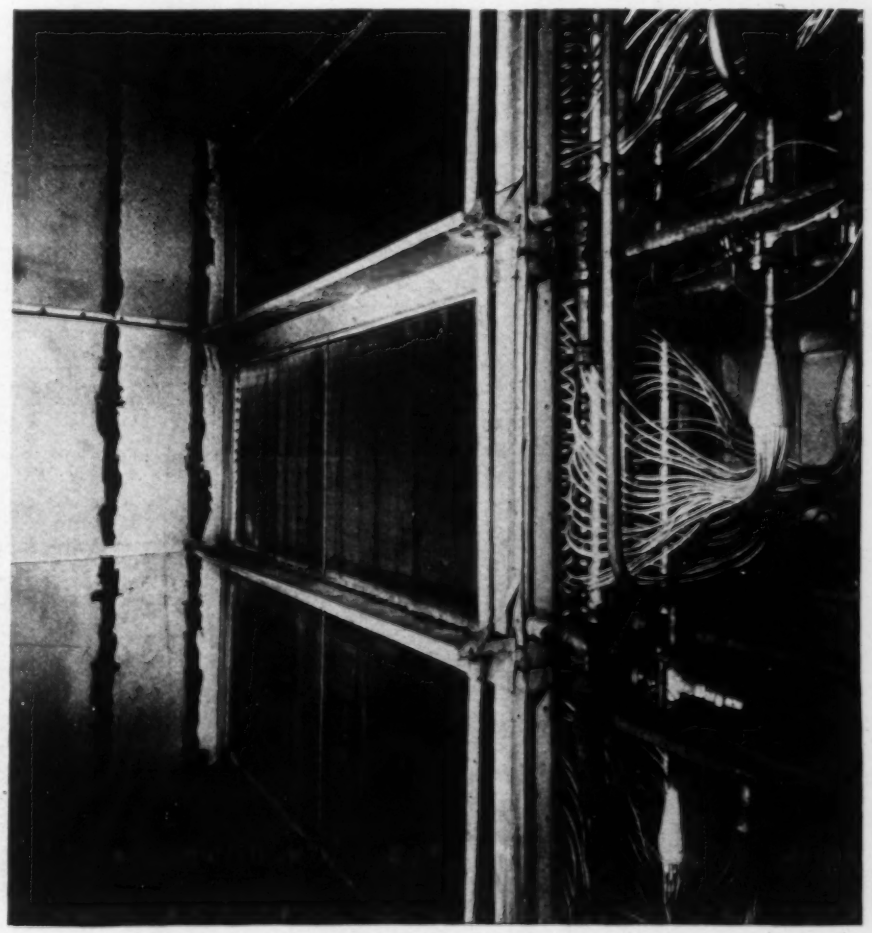
If you are the contentious type, you will want to prove to yourself that the coil must really be a six row and that 450 is the face velocity. Or you may accept the statement as true and give the design no further thought.

Myself, I have developed almost a fetish for proof of the design. This always leads to a discussion with the designer for more detailed information and in many cases a change in design conditions to obtain a working system without reheat or chemical dehumidification.

Typical of this condition, there follows a specification for a dining room in a small hotel: Outside conditions are 100 F dry bulb, 80 F wet bulb; inside conditions are 80 F dry bulb and 50 per cent relative humidity. Load conditions are 20,500 Btu space sensible heat, 35,500 Btu total space heat, with a ratio of sensible to total heat of 58 per cent. Outside air is 600 cfm. The total sensible heat is 32,500 Btu, grand total heat is 59,500 with a 0.55 ratio, 1000 cfm total air circulated.

Now, let's put these conditions on Fig. 1. $T_o$ (outside design) is 100 F DB, 80 F WB, 124 grains per lb of moisture. Air at $T_d$ (inside design) contains 77 grains per lb, or a difference of 47 grains per lb.

From the above specified load you will see the ventilation load was divided equally between sensible and latent at 12,000 Btu. From the psych chart, we find this cannot possibly be true. The sensible Btu can be calculated as $600 \times 20 \times (60 \times 0.24/13.7) = 12{,}600$, and this difference is negligible. The latent Btu is calculated as $600 \times 47$ grains $\times [(1070 \times 60)/(13.7 \times 7000)] = 18{,}900$, and this difference is more than can be neglected. Rearranging the original load gives this result: total sensible heat, 33,100 Btu; grand total heat, 67,000 Btu; ratio, 49.5 per cent.



These coils, serving a 2200 seat theater, are six rows deep, each arranged in two "clusters" for distribution of the "Freon". The first cluster carries 47 per cent of the load and the balance carries the remaining 53 per cent.

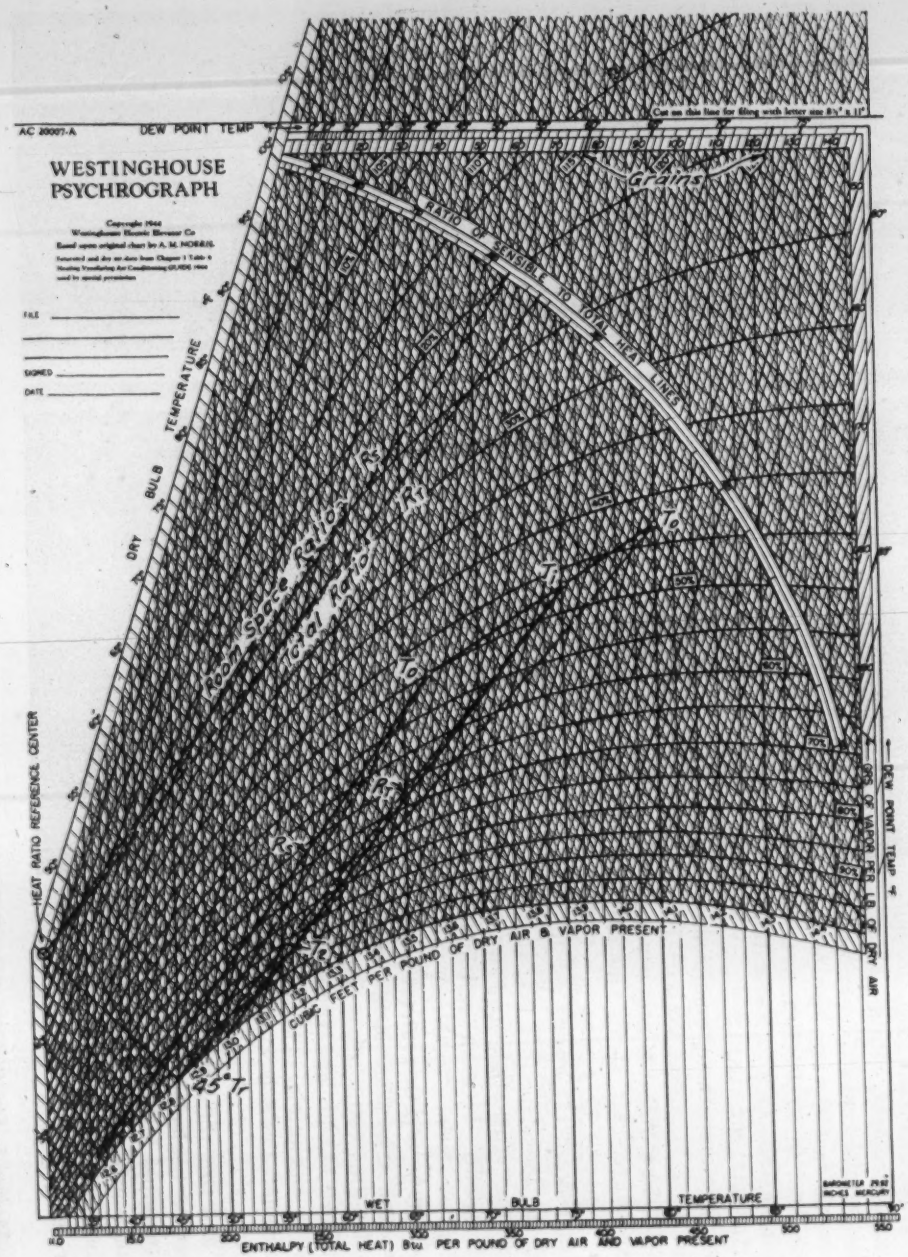
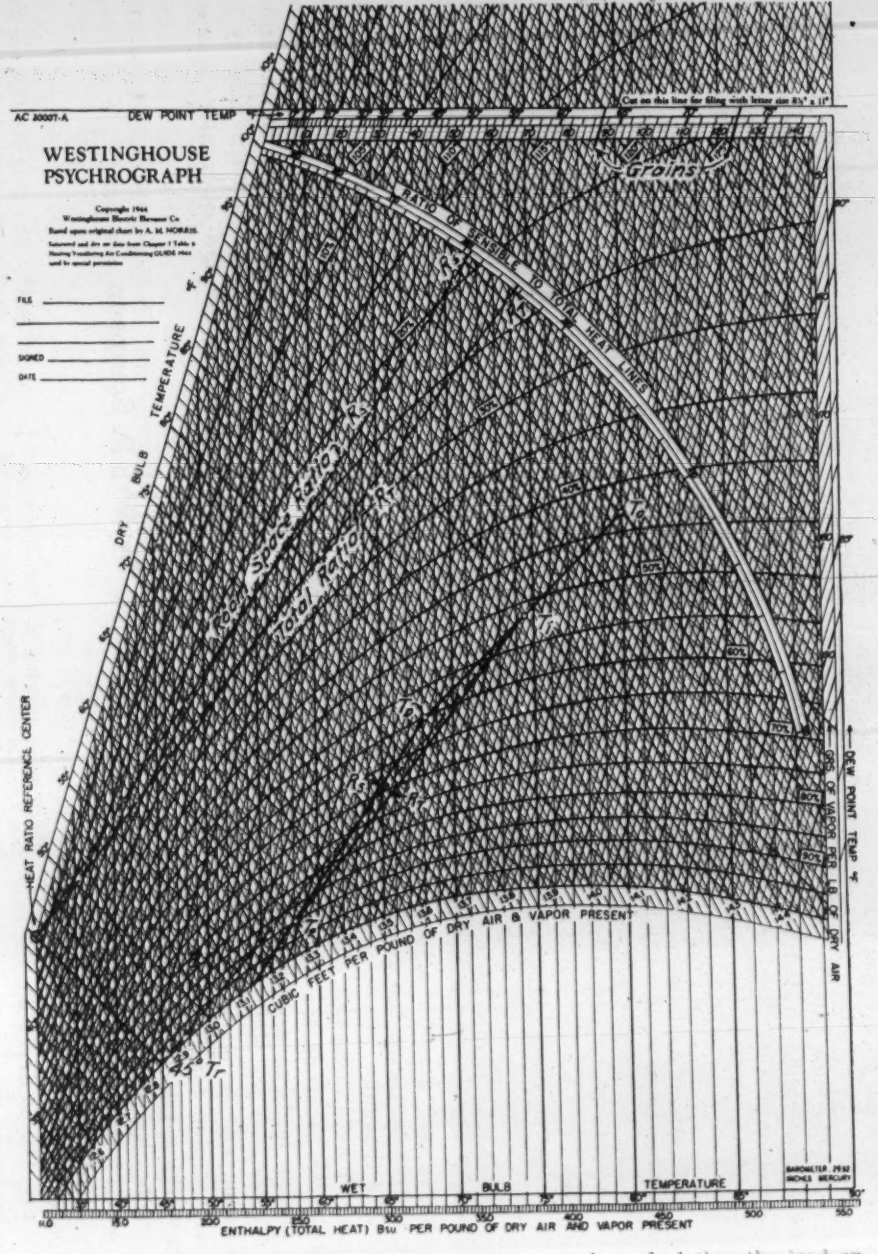

AC 20007-A
DEW POINT TEMP °F
WESTINGHOUSE
PSYCHROGRAPH
Grains
RATIO OF SENSIBLE TO TOTAL HEAT LINES
Room Space Ratio Rs
Total Ratio Rt
DRY BULB TEMPERATURE
HEAT RATIO REFERENCE CENTER
GRS OF VAPOR PER LB OF DRY AIR
CUBIC FEET PER POUND OF DRY AIR & VAPOR PRESENT
WET BULB TEMPERATURE
ENTHALPY (TOTAL HEAT) Btu PER POUND OF DRY AIR AND VAPOR PRESENT
BAROMETER 29.92 INCHES MERCURY

Fig. 1—Under these conditions it is impossible to get 80 F dry bulb and 50 per cent relative humidity without reheat, bypass, or chemical dehumidification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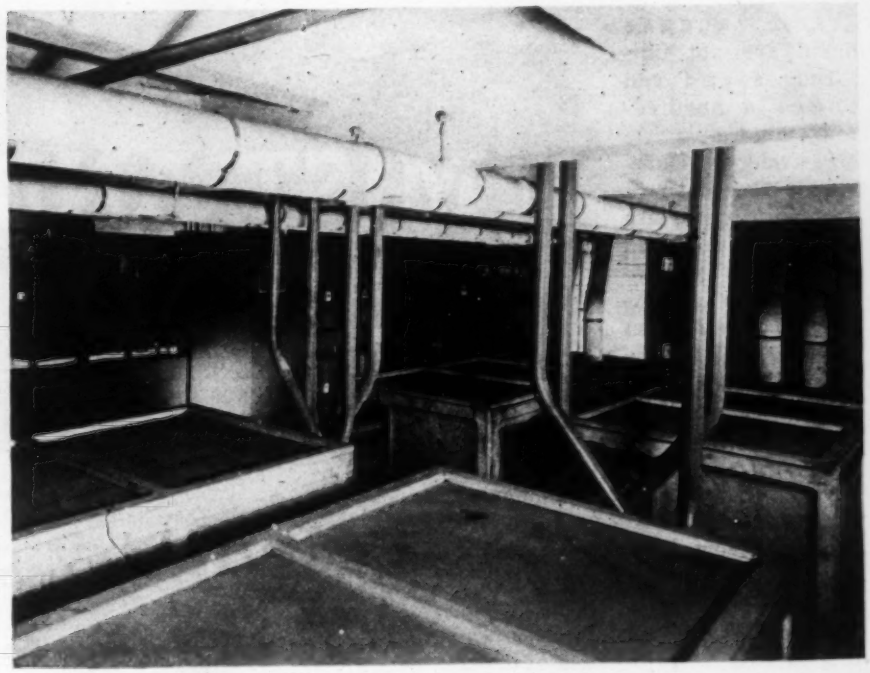
BAROMETER 29.92 INCHES MERCURY

Fig. 2—By changing the inside design conditions and recalculating the load on the new basis, the solution becomes possible and the coil selection can be made.



**Four 40 hp compressors for air conditioning a 2200 seat theater are located in the space caused by the balcony structure. Because the machines are above the heads of those on the lower floor and under the occupants of the balcony, sound absorption boxes were constructed over each of the compressors to close in any noise. Since these are gas cooled, hermetically sealed machines, this could be done without providing any special ventilation for the compressor motors**

It was further specified that this coil operate at a 45 F refrigerant temperature.

It is well known that the air that leaves this coil must be on the ratio line of sensible to latent heats from the design room conditions of the space heat gain. If it is not in this condition, the desired room design temperature will not be met or maintained.

### Refer to Psych Chart

Refer again to the psych chart, Fig. 1. From $T_d$ draw the room ratio line shown as $R_r$. Locate the refrigerant temperature $T_r$ on the saturation curve and 45 F dry bulb. Now, if there were no outside air at all, the most that could be expected from a coil would be represented by the dotted performance line from $T_d$ to $T_r$; if all outside air were used, the dotted line from $T_o$ to $T_r$ represents the performance. With the introduction of a percentage of outside air to total air, the entering air temperature lies at some point along a line drawn from $T_d$ to $T_o$. In our specific case, this point can be calculated from $(600/1000) \times (T_o - T_d) + T_d = 92$ F DB. This point will be found at $T_1$. The line from $T_1$ to $T_r$ represents the ultimate coil performance for this specific case. Therefore, the air leaving the coil cannot get any colder than 45 F dry bulb at complete saturation; this is pure theory and from practice it is known the air would in all probability not be better than 90 per cent saturated at a final temperature of about 58 F dry bulb, which is located at $T_2$.

Since the space ratio line from $T_d$ does not even cross the saturation curve and $T_2$ can be located from rule-of-thumb practice within 10 per cent of accuracy at 58 F DB and 90 per cent relative humidity, it is impossible to get 80 F dry bulb and 50 per cent relative humidity in the room without reheat, bypass, or chemical dehumidification no matter how many rows deep the coil may be or however low we drop its face velocity.

This is not meant to prove that one individual picked an impossible set of conditions. Many other similar cases could be cited, but for the sake of brevity further proof that this is prevalent is felt unnecessary. There are enough such errors actually occurring in the industry to warrant thought on the correction of these errors.

### How to Correct the Condition

The correction of this example may be done after a study of the comfort chart by changing the design conditions for inside from 80 F and 50 per cent to 78 F and 60 per cent relative humidity. By recalculating the load on this basis, the space sensible heat becomes 22,000 Btu, the total space heat 37,000 Btu, and the ratio 59.5 per cent. The total sensible becomes 35,900 Btu and the grand total becomes 65,800 Btu, with a ratio of 54.5 per cent. The grand total load drops from 67,000 to 65,800 Btu.

By referring to Fig. 2, observe that $T_o$ remains at 100 F DB and 80 F wet bulb. Drawing the internal space ratio line 0.595 from $T_d$, it crosses saturation at 59 F DB assuming 90 per cent saturation off the coil. $T_2$, the leaving air temperature, is 60 F DB. From $T_2$, drawing the total ratio to a line between $T_o$ and $T_d$, $T_1$ (the entering air condition) is established at 89 F DB. A line drawn from $T_1$ to $T_r$ represents—as said— the ultimate coil performance for this set of conditions. Since $T_2$ lies to the right of the theoretical line, it becomes a possible solution and coil selection can now be made from coil performance charts. These charts show a six row coil at 510 fpm face velocity will handle the job.

### "Air Conditioning Engineers Are 'Nuts'"

Did someone say the original design was not much in error? True, it isn't—except for one point. The guarantee called for 80 F dry bulb and 50 per cent relative humidity to be maintained and upon this basis the contract cannot be met. It becomes necessary to change conditions—which puts the customer, an innocent bystander, in the frame of mind that all air conditioning engineers are "nuts," that the industry is still in the guessing state, and that if it weren't for his customers forcing him to air condition, he'd tell us all to hold off until we had our business on a sounder basis.

# MIST AND DUST COLLECTION

## in Industry and Buildings

### *C. E. Lapple, du Pont Engineer, Reviews Methods of Representing Particle Size*

MOST PROCESS dusts are not uniformly sized and cover a hundredfold or more particle size range. Dusts with a relatively uniform particle size are quite rare and are usually associated with an extended classification process, as in the case of beach sand, or a special mode of formation, as by spray cooling or drying or vapor phase condensation. Generally process dusts are originally formed by some means of comminution and are introduced into gas streams by an inefficient and more or less random classification process, as in the case of dryer gases or ventilation hoods on dumping booths. As a result gasborne dusts generally have a limiting upper particle size but contain a gradation of particles all the way down to the very finest.

#### Frequency Plot

For purposes of interpretation or extrapolation of particle size of a dust containing such a wide variety of sizes, it is desirable to represent the particle size distribution either graphically or analytically. The most common type of plot is the frequency plot shown in Fig. 1.

Most crystalline and some amorphous materials have planes of minimum strength or incipient fracture, at which rupture takes place more readily during a comminution process. Thus there is a tendency to form preferentially particles of the size represented by the enclosure between such rupture planes since it becomes increasingly difficult to form finer particles. Physical laws controlling the formation of fumes, mists, or sprays also tend to form a preferential particle size. As a result, particle size distributions tend to approximate a probability relationship with a peak at the preferential size.

Curve 1 in Fig. 1 shows a normal probability distribution in which the distribution is symmetric about the preferential size. This form of curve is sometimes encountered, but is relatively rare. It is usually associated with dusts having relatively uniform particle size distributions, such as zinc oxide formed by vapor phase reaction and condensation or tar or acid mists, and is not usually found with dusts formed by comminution.

Curve 2 shows a skewed probability or frequency curve, which is the type usually obtained with comminuted dusts. Some materials show more than one preferential size, as indicated by curve 3. It should be pointed out that in a frequency distribution curve the fraction of particles within a narrow size range is plotted against the average size of the range. It is essential that a uniform system of selecting the extent of the incremental size range be adhered to in order to obtain an interpretable distribution plot. This fact is not usually stated in publications on the subject, but is generally implied.

For a given dust an infinite number of frequency distribution curves can be obtained depending on the method of selecting the incremental size range. The most common method is to select equal arithmetic increments of diameter for making the count. In one method the frequency is divided by the size increment involved and the quotient is plotted against some function of the size. This is what is often termed a "per cent per micron" frequency and is, in effect, the equivalent of using an increment of one micron throughout. This method has the advantage that no strict system of selecting increments need be adhered to. In the log-probability type of frequency distribution, which will be discussed later, equal increments of the logarithm of diameter are taken. This is the equivalent of splitting the particle size range into increments bounded by diameters having the same ratio to each other. This is automatically the case where a standard Tyler screen analysis is made since successive sieve apertures increase in the ratio of the square root of 2, or the fourth root of 2, depending on the screen series used.

#### Cumulative Particle Size Distribution

In a second method of representing particle size distribution, a cumulative curve is plotted (Fig. 2), in which the fraction of the total number or weight of particles which have a diameter greater (or less) than a given size is plotted against the size. This type of curve is generally the most useful for dust control work and is essentially an integrated form of the frequency curve.

In order to facilitate extrapolation or interpolation, various analytical relationships have been proposed to represent particle size distributions. All of these methods have their special merit and application but none is completely satisfactory. While many materials may follow one or the other of these relationships, they usually tend to deviate, sometimes very widely, at the extreme ends of the particle size range.

### Gaudin's Law

Gaudin's law (5)* is probably the simplest and is intended to represent the frequency distribution in the range of sizes smaller than that at which the peak frequency occurs. It is based on frequency in geometric or equal logarithmic size increments and is given by

$$(n/\Sigma n) = a\,D^b\,\Delta \log D \quad \ldots\ldots [1]$$

where the term at the left represents the fraction of the total weight of particles in a given size interval, $\triangle D$, of average size $D$. Schuhmann (13) has presented Gaudin's equation in integrated form

$$\phi = 100\ (D/a)^b \quad \ldots\ldots\ldots\ldots [2]$$

where $\phi$ is the cumulative per cent of material smaller than a given size $D$. The terms $a$ and $b$ are used simply to denote values that are constant for a given material and do not necessarily have the same values in these equations. In equations 1 and 2, the value of $b$ is the same, but values of $a$ are different. Both equations 1 and 2 will give straight lines when $(n/\Sigma n)$ or $\phi$ are plotted against $D$ on logarithmic paper. These relationships may often be used to express the finer end of a particle size distribution but are not satisfactory for the range above the 50 to 80 per cent undersize.

*Numbers in parentheses refer to the accompanying list of literature cited.

### Nomenclature

$a, b, c$ = constants, which may or may not be dimensional;
$d$ = "derivative of" = limiting value of $\Delta$;
$D$ = particle diameter, microns;
$D_m$ = mean diameter (arithmetic mean for normal probability distributions and geometric mean for log-probability distributions), microns;
$D_{mc}$ = mean diameter based on a count distribution, microns;
$D_{mw}$ = mean diameter based on a weight distribution, microns;
$e$ = natural or Napierian logarithmic base, 2.718 .....;
log = "common logarithm (to the base 10) of";
$n$ = number or weight of particles in a given size interval;
$\Sigma n$ = total number or weight of particles;
$\alpha$ = standard deviation (arithmetic standard deviation for normal probability distributions, microns; geometric standard deviaton for log-probability distributions);
$\alpha_c$ = standard deviation for count distributions;
$\alpha_w$ = standard deviation for weight distributions;
$\phi$ = cumulative per cent of material finer than a given size;
$\Theta$ = cumulative per cent of material larger than a given size $= 100 - \phi$;
$\Delta$ = "increment in."

### Other Proposed Relationships

Roller (11) has proposed a relationship of the form

$$\phi = a\ D^{1/2}\,e^{-(b/D)} \quad \ldots\ldots\ldots\ldots [3]$$

where $\phi$ is the cumulative per cent of material smaller than a given size $D$. This equation will plot as a straight line if log $(\phi/D^{1/2})$ is plotted against $(1/D)$. While this relationship may be used in the fine end of a particle size distribution, it generally does not apply for the range above 80 per cent undersize and actual distributions will usually show a reversal of the curve in the upper range.

Griffith (6) has recently proposed a complex cumulative relationship derived by the general methods of the theory of probability and by analogy to the statistical mechanics of gases. His equation is best represented by a frequency relationship based on equal size increments

$$(n/\Sigma n) = a\ D^{-b}\,e^{-(c/D)}\,\Delta D \quad \ldots [4]$$

where $(n/\Sigma n)$ is the fraction of

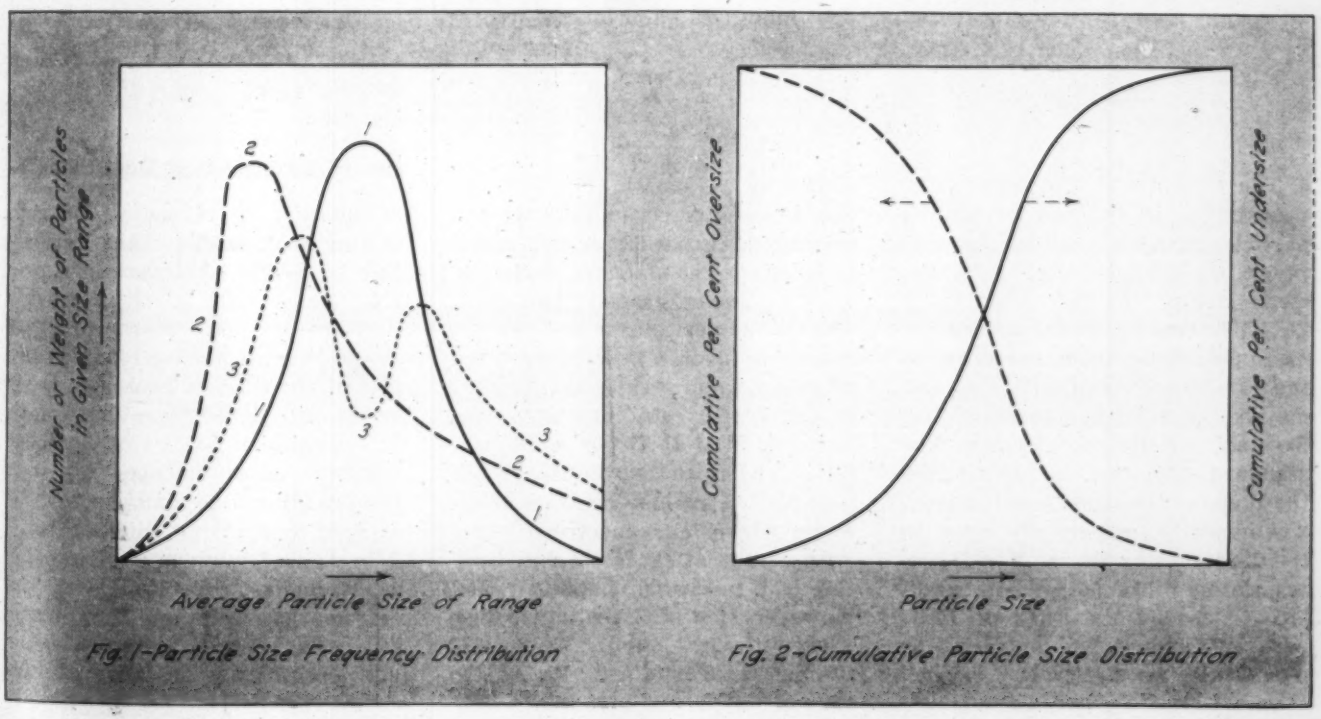

Number or Weight of Particles in Given Size Range
Average Particle Size of Range
Cumulative Per Cent Oversize
Cumulative Per Cent Undersize
Particle Size

Fig. 1—Particle Size Frequency Distribution

Fig. 2—Cumulative Particle Size Distribution

total material in a size range, $\triangle D$, having an average size $D$; and $a$, $b$, and $c$ are constants. Griffith also shows that this relationship becomes identical with Gaudin's equation for larger sized particles.

One of the more successful forms is that of Rosin and Rammler (2, 12):

$$\theta = 100\, e^{-(D/a)^b} \quad \ldots\ldots\ldots\ldots [5]$$

where $\theta$ is the cumulative per cent of material larger than size $D$ (i.e., $\theta = 100 - \phi$) and $a$ and $b$ are constants. This relationship will yield a straight line if the term, log log $(100/\theta)$ is plotted against log $D$, or if log $(100/\theta)$ is plotted against $D$ on logarithmic paper.

Graph paper can be prepared to represent $D$ on a log scale and $\theta$ or $\phi$ on a suitable log log scale so that a straight line is obtained when $D$ is plotted against $\theta$ or $\phi$. The value of $b$ is found from the slope of the curve and the term $a$ represents the particle size corresponding to the intercept with the 36.8 per cent oversize. Schuhmann's form of Gaudin's equation becomes identical with the Rosin-Rammler relationship at the finer particle end of the distribution.

### Probability Frequency Distribution Equations

Probably the most widely used are the probability frequency distribution equations in some form or other. The normal probability relationship may be written as

$$\left[\frac{n}{\Sigma n}\right] = \left[\frac{1}{\alpha\sqrt{2\pi}}\right] e^{[-(D-D_m)^2/2\alpha^2]}\,\Delta D \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The term $(n/\Sigma n)$ represents the probability or fraction of all the particles that lie in an incremental range of particle size, $\triangle D$, the mean size of the increment being $D$. The term $D_m$ is the arithmetic mean diameter, corresponding to the 50 per cent cumulative size, and may be regarded as a constant that fixes the position of the curve. The standard deviation, $\alpha$, determines the shape of the curve and is a positive quantity, numerically equal to the difference in the value of $D$ corresponding to the 50 per cent cumulative size and the 84.13 or 15.87 per cent cumulative undersize or oversize. When $n$ is plotted against $D$ on arithmetic paper, a symmetrical curve similar to curve 1 of Fig. 1 is obtained with a peak at $D_m$. The cumulative size distribution is given by integration of equation 6, since $d\phi = 100\,(n/\Sigma n)$,

$$\phi = \left[\frac{100}{\alpha\sqrt{2\pi}}\right] \int_0^D e^{[-(D-D_m)^2/2\alpha^2]}\, dD \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

While equation 7 cannot be integrated and solved algebraically to express $\phi$ as an explicit function of $D$, it can be evaluated from tables of the probability integral and graph paper is available (3) which represents $D$ on an arithmetic scale and $\phi$ on a probability scale such that a straight line is obtained when equation 7 is satisfied.

It has been found that by using the term "log $D$" in place of $D$ in the probability equation, a closer approximation is obtained to most actual particle size distributions. For such a log-probability relationship, the frequency and cumulative distribution may be respectively written as:

$$\left[\frac{n}{\Sigma n}\right] = \left[\frac{1}{(\log\alpha)\sqrt{2\pi}}\right] e^{[-(\log D - \log D_m)^2/2\log^2\alpha]}\,\Delta(\log D) \quad \ldots\ldots\ldots (8)$$

$$\phi = \left[\frac{100}{(\log\alpha)\sqrt{2\pi}}\right] \int_0^D e^{[-(\log D - \log D_m)^2/2\log^2\alpha]}\, d(\log D) \quad \ldots\ldots\ldots (9)$$

In these equations $(n/\Sigma n)$ represents the probability or fraction of all the particles that lie in an incremental logarithmic or percentage range of particle size represented by $\triangle(\log D)$. The term $D_m$ is the geometric mean diameter and corresponds to the 50 per cent cumulative size. The standard deviation, $\alpha$, is a number greater than unity and is numerically equal to the ratio (or inverse ratio as required to give a value greater than unity) of the 50 per cent cumulative size to the 84.13 or 15.87 per cent cumulative undersize or oversize. When $n$ is plotted against log $D$ on arithmetic paper, a symmetrical curve with a peak at $D_m$ is obtained similar to a normal probability curve. However, if $n$ is plotted against $D$, a skewed curve similar to curve 2 of Fig. 1 is obtained. As in the case of the normal probability relationship, graph paper can be prepared on which equation 9 will plot as a straight line. The method of preparing such paper is described by Hazen (9). Graph paper of this type is commercially available (4) and presents $D$ on a log scale versus $\phi$ on a suitable probability scale as shown in Figs. 3 and 4.

### Count or Weight Basis

In the above probability equations, $n$, $\Sigma n$, and $\phi$ may be represented on either a count or a weight basis. To indicate whether the equation is based on a count or weight basis, the terms $D_m$ and $\alpha$ are given subscripts $c$ and $w$ to indicate a count and a weight basis, respectively. Hatch (7) has shown that for cases where the log-probability equations apply, $\alpha_c$ is equal to $\alpha_w$ and the curves for a count and weight basis will plot as straight parallel lines on log-probability paper. The geometric mean diameters are then related by the equation

$$\log D_{mw} = \log D_{mc} + 6.908 \log^2\alpha \quad [10]$$

where the subscript has been dropped from $\alpha$ since the two are identical.

### Use of Fractionated Dust Samples

Equation 10 is useful for converting microscopic count analysis over to weight analyses. In a previous paper (10) it was suggested that microscopic count analyses should be made on fractionated samples of the dust to avoid the large errors introduced by a small error in counting a few large particles. In many cases the need for thus fractionating the sample can be avoided by applying equation 10.

In Table 1 is given a microscopic count analysis together with the customary calculations for directly converting it to a weight analysis and both series of analyses are shown plotted on log probability

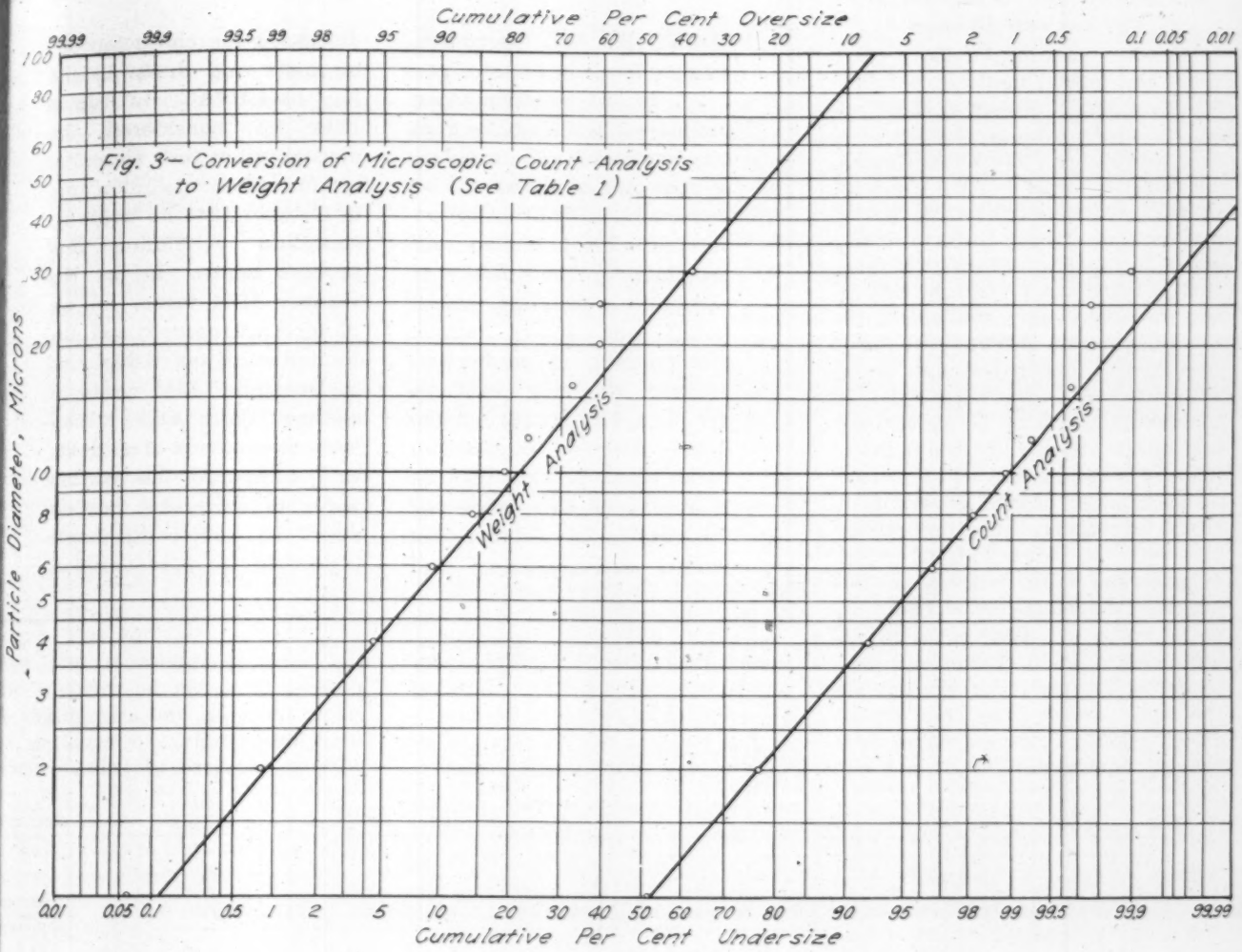



Fig. 3—Conversion of Microscopic Count Analysis to Weight Analysis (See Table 1)

paper in Fig. 3. It will be noted from Table 1 that a small error in counting a few large particles may result in a large error in the calculated weight analysis, whereas it will not appreciably affect the main portion of the count analysis. Such an error is more than likely, unless a great many fields are counted, due primarily to a non-representative nature of the particular field with respect to the coarse particles. However, in a case like this, the count analysis, which is probably fairly accurate over all but the coarse particle size range, can be represented by a straight line on a log-probability plot. This line is probably more accurate in the coarse range than the actual count for the reasons given.

From this line the value $D_{mc}$ is found to be 0.94 micron by the intercept with the 50 per cent line. The value $a_c$, which is also equal to $a_w$, is found to be 2.79 by taking the ratio of the 84.13 per cent undersize, which is 2.62 microns, to $D_{mc}$. The value of $D_{mw}$ is then computed from equation 10 to be 22.1 microns. By drawing a parallel line through 22.1 microns as the 50 per cent size, the weight distribution curve is obtained. It will be observed that this line fits the calculated data fairly well and removes the uncertainty due to the scattering of points in the larger particle size range.

**Table 1—Typical Microscopic Count Particle Size Analysis**

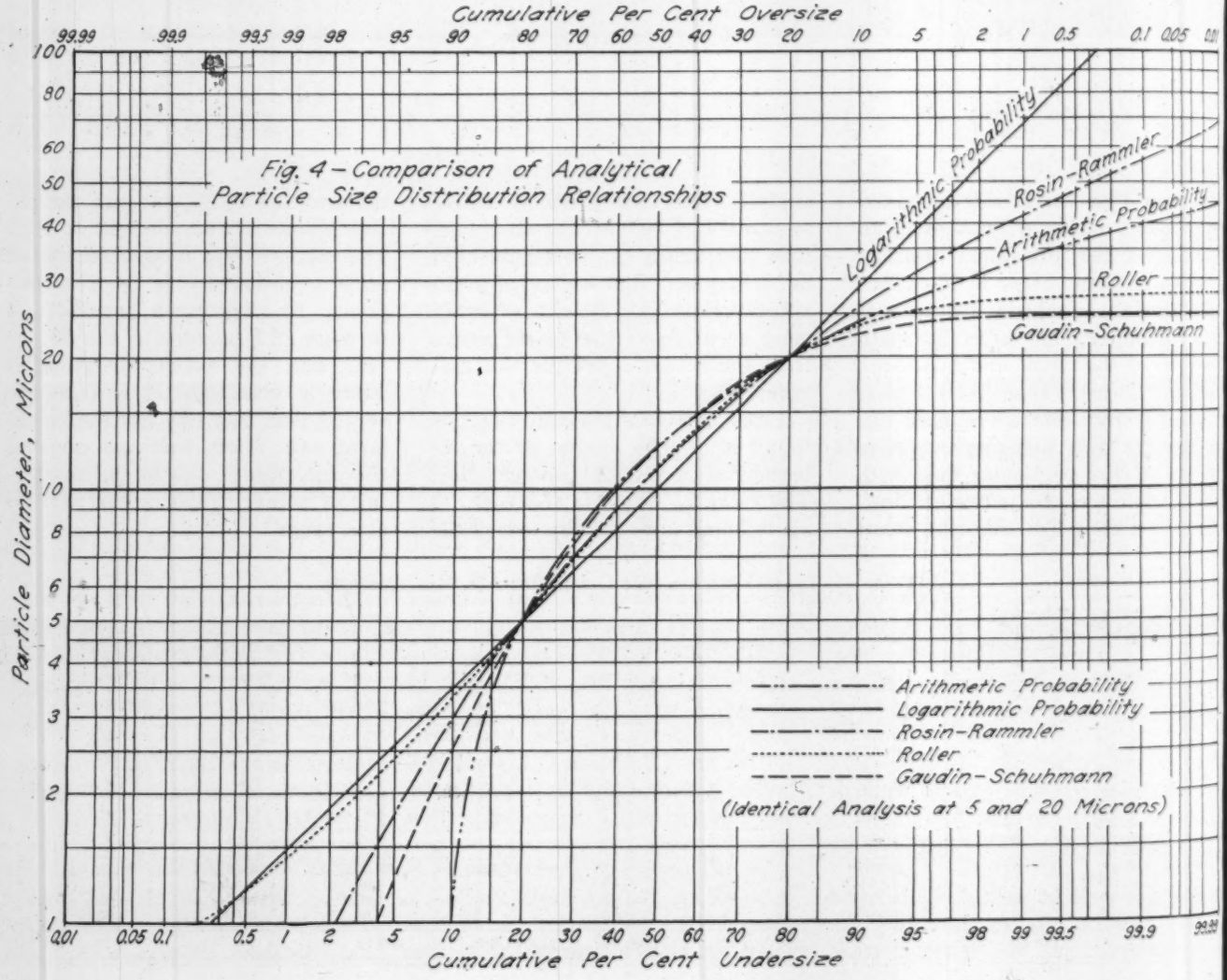
| Particle Size Range Microns | Average Size of Range $D$ Microns | $D^3$ | Number Particles in Field, $n$ | % by Number in Range | Relative Weight, $n D^3$ | % by Weight in Range | Cumulative % Larger Than Bottom Size of Range By Number | By Weight |
|---|---|---|---|---|---|---|---|---|
| 0-1 | 0.5 | 0.13 | 416 | 51.81 | 54 | 0.06 | 100.00 | 100.00 |
| 1-2 | 1.5 | 3.4 | 201 | 25.03 | 683 | 0.76 | 48.19 | 99.94 |
| 2-4 | 3. | 27 | 124 | 15.44 | 3,345 | 3.71 | 23.16 | 99.18 |
| 4-6 | 5 | 125 | 34 | 4.24 | 4,250 | 4.70 | 7.72 | 95.47 |
| 6-8 | 7 | 343 | 13 | 1.62 | 4,460 | 4.94 | 3.48 | 90.77 |
| 8-10 | 9 | 729 | 6 | 0.75 | 4,373 | 4.84 | 1.86 | 85.83 |
| 10-12 | 11 | 1,331 | 3 | 0.38 | 3,993 | 4.42 | 1.11 | 80.99 |
| 12-16 | 14 | 2,744 | 3 | 0.37 | 8,232 | 9.11 | 0.73 | 76.57 |
| 16-20 | 18 | 5,832 | 1 | 0.12 | 5,832 | 6.45 | 0.36 | 67.46 |
| 20-25 | 22.5 | 11,391 | 0 | 0.00 | 0 | 0.00 | 0.24 | 61.01 |
| 25-30 | 27.5 | 20,797 | 1 | 0.12 | 20,797 | 23.01 | 0.24 | 61.01 |
| 30-35 | 32.5 | 34,328 | 1 | 0.12 | 34,328 | 38.00 | 0.12 | 38.00 |
| 35-40 | 37.5 | 52,734 | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 |
| 40-50 | 45 | 91,125 | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 |
| >50 | >50 | >125,000 | 0 | 0.00 | 0 | 0.00 | 0.00 | 0.00 |
| Totals | | | 803 | 100.00 | 90,350 | 100.00 | | |

### Advantages and Disadvantages of the Methods Discussed

Whereas each of the above relations has special merit in particular cases, rarely do any of these relations apply over the entire particle size range. The Rosin-Rammler relation seems to give the best fit for actual distributions in the majority of cases. Unfortunately, a graph paper on which this relation will plot as a straight line is not commercially available, although various authors (2) have employed such a paper. Log-probability paper, on the other hand, is commercially available (4) and actual distributions will often approximate a straight line when plotted on such paper or will show only a slight curvature. Log-probability also has the advantage of being symmetrical with respect to the per cent undersize or oversize at both ends of the distribution, whereas Rosin-Rammler paper tends to emphasize or spread out the fine particle size end of the distribution. Consequently, even though a straight line is not obtained, log-probability offers a very convenient means for the graphical presentation of particle size data.

If a straight line is obtained on such a plot, other particle properties, such as specific or total particle surface, can be computed directly from $D_m$ and $a$ by means of equations similar to equation 10 without recourse to tedious incre-

**"DUST IS ALL pervasive, everywhere, on land or sea . . . in all manufacturing processes; in the smoke from our furnaces." The problem of dust and mist control and collection is constantly receiving more attention and prominence, in order to eliminate nuisances, guard health and safety, reduce maintenance of equipment, recover valuable products, etc. . . . Mr. Lapple, of the design division, engineering department, E. I. du Pont de Nemours & Co., reviewed the purpose of mist and dust control and collection, and discussed the characteristics of mists and dusts, in the July 1944 HPAC. In August 1944 he considered the measurement and character of atmospheric pollution, and in October 1944 he wrote on sampling ventilation and process gases. In the November 1944 issue, he explained microscopic and elutriation analyses of dust, and in December 1945 wrote on sedimentation and miscellaneous methods of analysis, and compared the various ways of analyzing particle sizes. His subject this month is particle size representation.**


Cumulative Per Cent Oversize
99.99 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.1 0.05 0.01
100 80 60 50 40 30 20 10 8 6 5 4 3 2 1
Particle Diameter, Microns
Logarithmic Probability
Rosin-Rammler
Arithmetic Probability
Roller
Gaudin-Schuhmann
Arithmetic Probability
Logarithmic Probability
Rosin-Rammler
Roller
Gaudin-Schuhmann
(Identical Analysis at 5 and 20 Microns)
0.01 0.05 0.1 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.99
Cumulative Per Cent Undersize
Fig. 4 – Comparison of Analytical Particle Size Distribution Relationships

mental numerical summations, as explained and discussed by Hatch and Choate (7, 8). Even where a straight line is not obtained, a calculation of specific surface, for example, which is largely determined by the finer sizes, can often be calculated with sufficient accuracy directly from a straight line drawn through the fine size range.

A cumulative plot of either the Rosin-Rammler or log-probability type is sometimes objected to on the grounds that it desensitizes the data. For the greatest sensitivity a frequency distribution type of plot is preferred. For dust control work, however, the desensitization achieved by a cumulative plot can hardly be considered an objection and, on the contrary, may be advantageous in view of the practical limitations of present methods of particle size analysis.

The Gaudin or Schuhmann relations lend themselves readily to simple mathematical manipulation but are not suitable for presenting the coarse particle size end of a distribution. The Roller and Griffith relations do not lend themselves to a direct plotting of particle size against percentage oversize or undersize as do the others and are also not applicable to the coarse size end of the distribution curve. While they approach a log-probability relationship at the fine particle size end, they would appear to have little practical merit.

Austin (1) has given a good review of some of these methods of particle size representation and presents actual particle size data plotted according to these various methods, with emphasis on the log-probability type of plot.

In order to illustrate the comparative shapes of particle size distribution curves that follow the various analytical relationships described above, Fig. 4 has been prepared. In each case the cumulative weight per cent of material finer than 5 and 20 microns has been taken as 20 and 80 per cent, respectively. The rest of the distribution was then computed so that the respective relationship involved was satisfied and all the distribution curves thus obtained have been plotted on log-probability paper. On such a plot, the log-probability relationship will, of course, show up as a straight line.

It will be noted that the curves all tend to approach straight lines in the finer particle end of the distribution, in which range any of these methods can usually be applied to distributions obtained in practice. In this particular plot, however, the curves do not coincide in this range since the coincident points were selected at 20 and 80 per cent cumulative undersize. It will be noted that the Gaudin and Roller relationships level off very rapidly in the size range above the 50 per cent size. Usually, distributions obtained in practice will yield curves that are intermediate between the log-probability and Rosin-Rammler relationships, probably closer to the latter, as a comparison with Fig. 4 on page 614 of the December '45 HPAC will illustrate.

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## APARTMENT AIR CONDITIONING ESTIMATED TO COST $15.30 PER ROOM PER SEASON

Air conditioning can be included in postwar apartment building developments at a cost to the tenant of approximately $1.27 a month per room, says the Refrigeration Equipment Manufacturers Association.

The estimate is based on a study which indicates that a modern apartment in a temperate climate can be air conditioned during the warm season at a total cost of about $15.30 a room, or $1.27 a month over a year.

The cost "includes a complete return on the initial investment in air conditioning equipment in 20 years, taxes, administration, electrical energy, condenser water, operating labor, repairs, and 6 per cent interest on the unreturned investment."

The above figures, REMA says, indicate that air conditioning is not a luxury beyond the reach of the person with an average income, but rather a basic comfort which can be provided at small additional cost to apartment dwellers.

# Vast Field for Both Air Conditioning, Evaporative Cooling But Results to Be Expected Are Different

THE EDITOR—I am very much interested in H. A. Mosher's comments [pages 620-621 in the December issue] on the remarks of others in connection with his articles, When Is Complete Air Conditioning of the Modern Factory Advisable?, and the relationship of this question as to "how evaporative cooling would stack up as compared to complete air conditioning."

As you well know, I am extremely interested in evaporative cooling for comfort. Straight ventilation without any means of sensibly cooling the air, of course, can never compete with refrigerated air conditioning, no matter how much air is circulated, if a temperature in the enclosure below the outside dry bulb temperature is required. In evaporative cooling it is obvious that no dry bulb temperature can be obtained lower than the prevailing outside wet bulb temperature, and as the effective temperature* with which Mr. Mosher is so intensely interested is the temperature of saturation, it is obvious that no 72 deg effective temperature can be obtained (or anything like that) with a 75 deg or higher outside wet bulb temperature.

We, therefore, have to approach this whole subject from the angle of what is a suitable or bearable or desirable condition for summer occupancy, particularly in industrial establishments. I am always a bit perturbed when isolated statements are culled from the records of the ASHVE to create an impression that unless certain definite things were done—particularly in connection with physiological reactions of human beings—the conditions that would obtain, in the minds of the public, might mean unhealthful conditions. When we speak of "ideally designed ventilating systems capable of providing comfort to 75 per cent of moderately active workers," and these conditions can only be obtained with refrigeration, we certainly are opening all of our industrial establishments to a critical interpretation by labor that is not warranted, I believe, by the facts.

### Determining the Maximum Effective Temperature

Over a period of a good many years the ASHVE carried on a series of tests to find the reactions of human beings to various simultaneous conditions of temperature and humidity. The majority of the subjects, of whom most were office workers in sedentary occupations, expressed a preference for an effective temperature of around 72 deg. This corresponded to a dry bulb temperature of about 78 F with a 50 per cent relative humidity. These were conditions that were set up by some of us in the early days of air conditioning as desirable conditions in the theater. However, these tests showed that these same people at a higher effective temperature felt comfortably warm. The reactions to "comfortably warm" were better than to "cool," which was the datum line below "ideally comfortable." Following these tests or investigations covering degrees of comfort reactions, a series of investigations was carried on to find out at what point of elevated temperatures and humidities unusual physiological reactions took place. This type of investigation was actually the very first type of investigation started by the research of the ASHVE in conjunction with the Bureau of Mines.

When, in 1935 or 1936, a committee on air conditioning in industry was inaugurated under my direction, the idea was to check the early investigations in order to determine what was safe or proper for people in industry. This investigation—which was carried on not only by the various people mentioned by Mr. Mosher, but under varied conditions for the Navy, which series of investigations can now be divulged—confirmed the earlier results not only of our own laboratory but also of Haldane and others in Europe. No particularly unfavorable reactions were noticed until a condition of about 87 deg effective temperature was reached with men mildly exercising. Notwithstanding anything stated by Mr. Mosher to the contrary, a 78 deg effective temperature for people moving or standing was considered comfortable by all of the subjects.

Within the last few days, Navy information which was secret during the war has been released confirming the investigations which were made by the committee on air conditioning in industry to the effect that as far as ability to carry on set efficiency-work tests for practically an infinite length of time is concerned, 80 deg effective temperature is not only safe but not particularly uncomfortable. Assuming, therefore, that the Navy for its highly important work could find no reason for producing conditions better than 80 deg effective temperature, why not start with 80 deg as a basis and see what the comparative cost of installation and operation of producing such results by means of refrigeration versus evaporative cooling would be?

* The effective temperature is (says the ASHVE's Heating, Ventilating, Air Conditioning Guide 1945) an arbitrary index which combines into a single value the effect of temperature, humidity, and movement of air on the degree of warmth or cold felt by the human body. The numerical value is that of the temperature of still, saturated air which would induce the identical sensation of warmth.

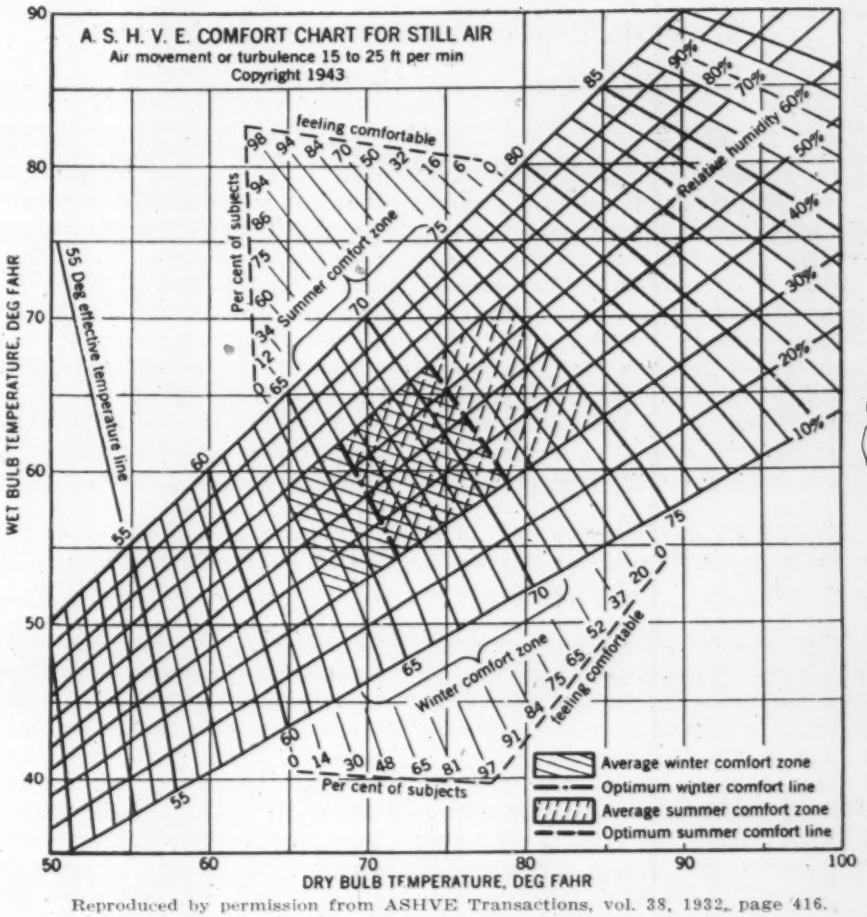
## "OPEN for DISCUSSION"

## "Refrigerated" Air Conditioning and Evaporative Cooling

Of course, it is my opinion that anyone buying refrigerated air conditioning would insist on effective temperatures lower than 80 deg, and consequently it is hardly fair to compare refrigerated air conditioning at 80 deg effective with evaporative cooling at 80 deg effective. The probabilities are that the purchaser of a refrigerated air conditioning system would demand a temperature of 72 deg effective where he might be perfectly satisfied with 80 deg effective with evaporative cooling, realizing that a great deal of the time a condition better than that could be obtained with the evaporative cooling method.

The method of figuring the two jobs is exactly the same so far as the heat rise is concerned, except that with evaporative cooling the dry bulb temperature inside the enclosure would probably be higher than with refrigerated conditioning and, therefore, less sensible heat would have to be taken care of. This would reduce the amount of air that had to be introduced for maintaining the desired condition. When the calculations were completed, it would probably be found that to maintain under the worst conditions an 80 deg effective temperature with evaporative cooling would require only a third more air than would be required with a refrigerated system to maintain that "ideal" condition mentioned in Mr. Mosher's articles. This additional 33 per cent of air would increase the basic cost of the air moving system possibly 25 per cent. However, to this cost with refrigerated air distribution would have to be added the entire refrigeration equipment including coils or washers and the refrigeration apparatus itself with condensers and cooling towers, which in the average, large size job would run about twice as much as the basic air moving system—so that the refrigerated system would cost nearly three times as much as an adequate effective cooling system, instead of about the same as suggested by Mr. Mosher.

I don't believe it is necessary to go into the question of operating costs. The evaporative cooling system would require very little additional power to operate than the air moving system of the refrigerated system. The entire operation of the refrigerating system, with its compressors, pumps, etc., would have to be added during the entire summer or cooling period—to which, of course, would have to be added interest or depreciation on the increased investment.


A. S. H. V. E. COMFORT CHART FOR STILL AIR
Air movement or turbulence 15 to 25 ft per min
Copyright 1943
WET BULB TEMPERATURE, DEG FAHR
DRY BULB TEMPERATURE, DEG FAHR
Relative humidity
Per cent of subjects feeling comfortable
Summer comfort zone
Winter comfort zone
55 Deg effective temperature line
Average winter comfort zone
Optimum winter comfort line
Average summer comfort zone
Optimum summer comfort line

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**ASHVE comfort chart for still air**

*Note*—Both summer and winter comfort zones apply to inhabitants of the United States only. Application of winter comfort line is further limited to rooms heated by central station systems of the convection type. The line does not apply to rooms heated by radiant methods. Application of summer comfort line is limited to homes, offices and the like, where the occupants become fully adapted to the artificial air conditions. The line does not apply to theaters, department stores, and the like where the exposure is less than 3 hr. The optimum summer comfort line shown pertains to Pittsburgh and to other cities in the northern portion of the United States and southern Canada, and at elevations not in excess of 1,000 ft above sea level. An increase of 1 deg ET should be made approximately per 5 deg reduction in north latitude.

### Big Field for Both

My main criticism of Mr. Mosher's articles is that he assumes that an ideal condition (or "so-called ideal condition," whatever that may mean) is essential for the improvement or alleviation of summer conditions brought about by various industrial operations. Maybe loosely worded conclusions of American Society of Heating and Ventilating Engineers research articles are responsible for this. In many of the warm or hot industries (copying Mr. Mosher) I might say "complete" satisfaction can be obtained with evaporative cooling. In many places, however, evaporative cooling gives only partial satisfaction. There is a vast field for both refrigerated air conditioning and evaporative cooling, but their designed conditions are different and the results to be expected are different. However, as to their relative first costs or the cost of operation, there can be no possible question as to the favorable position that evaporative cooling holds.—WALTER L. FLEISHER, consulting and advisory engineer; member of HPAC's board of consulting and contributing editors.

# Intermittent Occupancy Must Be Considered in Church Heating

THE EDITOR—I am glad that Sam Lewis, in his article on church heating in the January issue, mentioned intermittent occupancy (or, more correctly, intermittent heating) of a building and the consequent additional load on the heating plant for heating up all of that cold material. The lack of information and the lack of realization that such a problem exists has caused thousands of churches to waste their money, first, by putting in inadequate heating plants, and, second, by burning the amount of fuel that an inadequate heating plant always requires to give even approximate results.

There is no published information as to how much should be added to the capacity of a heating plant to take care of this problem and Mr. Lewis offers no suggestion. In our experience, however, in handling nearly a thousand churches with furnace fan systems, we have found it necessary to add approximately 50 per cent to the estimated heat loss of an intermittently heated church with interior wood construction and not too heavy walls in order to handle that extra load as expeditiously and as economically as it should be. On some of the more modern churches, built of reinforced concrete, we find it necessary to double the estimated heat loss load to take care of this heating up load.

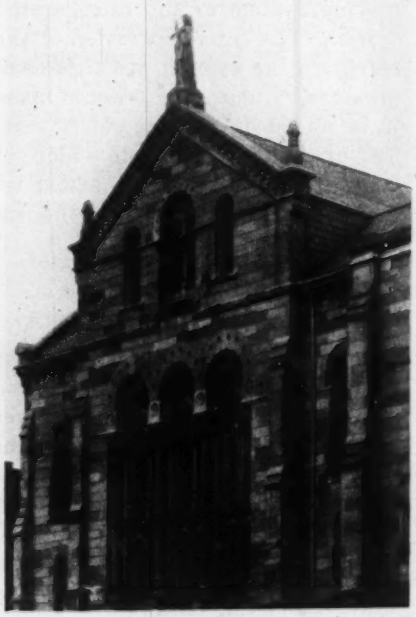
### Load Due to Heat Loss and Heat Absorption

Dr. F. E. Giesecke, of Texas A. & M., has shown much interest in this subject and calculated the point at which the combined load of normal heat loss and heat absorption by the cold building becomes the greatest; it is when the building reaches about 62 or 64 F inside that the greatest load occurs. He also verified our experience by calculating that in his particular building it would be necessary to add about 75 per cent to the capacity of the heating plant in order to do a good job. So, I am glad Mr. Lewis has called attention to this particular thing which is not so very generally recognized.

Mr. Lewis said that it is not difficult to heat a large auditorium with a fan system; that is correct, and distributing ducts are not necessary in most cases. A large volume of air delivered at a mild temperature gives even distribution, quick heating, and wastes less heat at the ceiling than any other method. It draws the cold air off the floor quickly should it ever fall down from the windows as Mr. Lewis indicated is a frequent trouble in his experience, so that that trouble with the windows does not occur in an auditorium heated by ample air movement. In our experience we have never had any trouble with either the clerestory windows or the large window behind the balcony.

Our preference for the warm air furnaces, direct fired, for church heating is based on the fact that they waste less heat getting started, they act more quickly, and the temperature of the air entering the auditorium can be controlled both by slowing down the fire and by opening the outside air dampers.

This system also has the advantage of providing the necessary blower and ducts through which cool air can be blown in in the summer from whatever source of cooling may be available. In Indianapolis we have a number of cooling systems using about 55 F well water, pumped through coils. In some of the dryer climates, we have them using air washers as evaporative coolers, and in a few cases we have in successful operation the storage system of mechanical refrigeration in connection with the furnace fan system which Mr. Lewis mentioned.



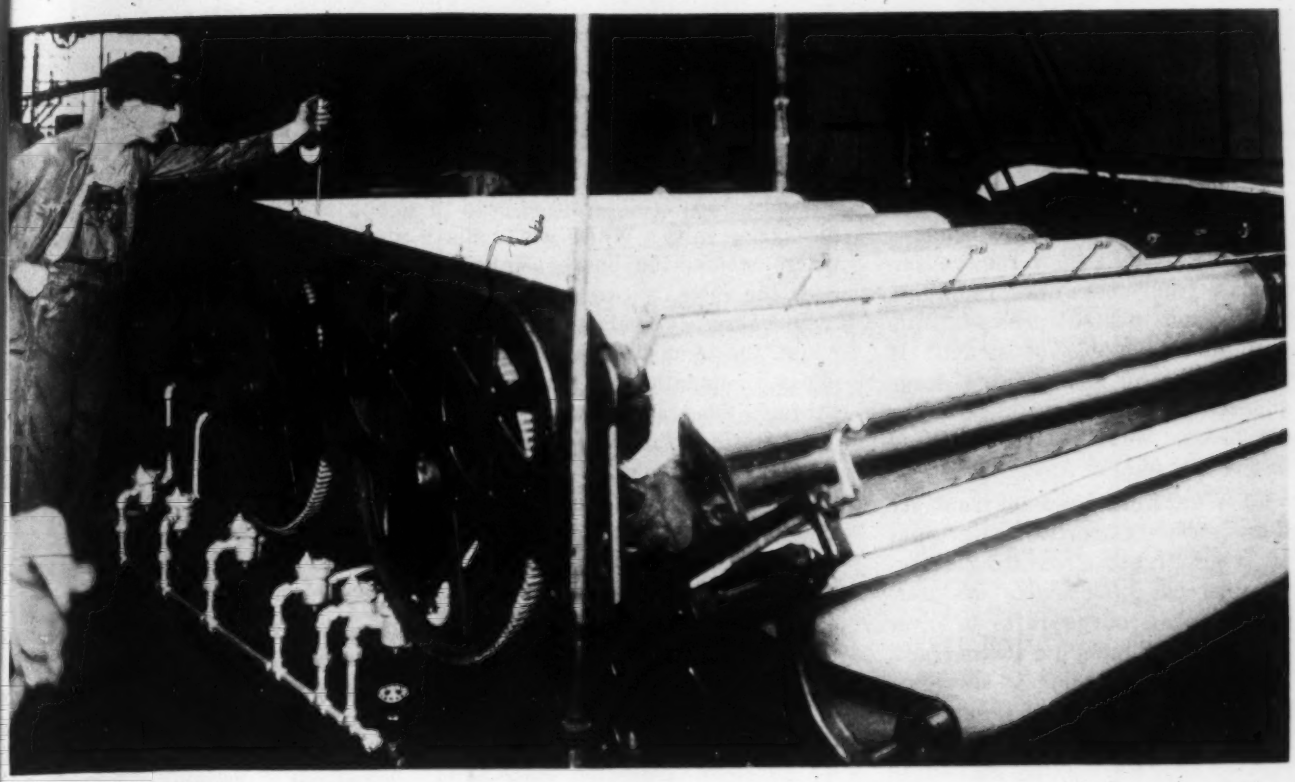
I congratulate you on bringing this subject up for discussion. It is one which needs to be discussed in that there are many things about it that are not generally understood and that lack of understanding consequently makes trouble in many churches.—E. K. CAMPBELL, E. K. Campbell Heating Co.

## CONTROLLING SCHOOLROOM UNIT VENTILATORS

THE EDITOR—Concerning Lewis Smith's remarks regarding control of unit ventilating machines in school building classrooms, in "Open for Discussion" in the January issue, he stated that due to a variable high vacuum maintained on the steam side he has been able to satisfy himself that no valve whatever is necessary on the steam supply to the convector in the unit ventilating machine and that an orifice in the steam supply to the auxiliary direct radiator in the same room is all that is required.

I submit that almost every class room receives solar heat at some hour of the day and that 40 children and their teacher carry in a very considerable amount of heat. Therefore, automatic temperature control definitely is necessary to prevent overheating, regardless of the steam temperature. Also, the radiator receives air presumably at 70 F while the convector receives air at variable outdoor temperatures. The two conditions definitely are incompatible.

I shall continue to require a duct thermostat to prevent entry of too-cool outside air and a separate thermostat in the room to control the auxiliary radiator. This is not to decry the value of a variable steam temperature following changes in outdoor temperature, such as is obtainable with subatmospheric steam. —SAMUEL R. LEWIS, consulting engineer, and member of HPAC's board of consulting and contributing editors.



# PIPING MAINTENANCE

***A VALUABLE feature of the wartime National Fuel Efficiency Program was the extensive series of "quiz sheets" containing tips on methods of conserving fuel in the use, operation, maintenance, and repair of various items of piping, heating, and air conditioning equipment. Because fuel conservation—a wartime necessity—is always good business and sound engineering, HPAC is publishing the information from these sheets. Practical pointers on separating steam traps and return or pumping steam traps—important items of piping equipment—are given this month. More of the data will appear later.***

ONE OF THE most valuable features of the National Fuel Efficiency Program, conducted during the war in cooperation with the U. S. Bureau of Mines, was the extensive series of "quiz sheets" on fuel efficiency developed in cooperation with various manufacturer groups and distributed by the program's regional engineers to "waste chasers" in individual plants and buildings. Because the information from these sheets is still just as valuable as it was during the war (saving fuel is always good business), we plan to print a number of them from time to time in HPAC, with the approval of the National Fuel Efficiency Section of the Bureau of Mines, which is part of the U. S. Department of the Interior.

In this issue appear the sheets on separating steam traps and return or pumping steam traps, both prepared by a committee of steam trap manufacturers. These were Nos. 135 and 136, respectively, in the series.

We are omitting from each of the sheets the final question: "What are your suggestions for saving fuel and preventing waste?" Perhaps this question is the most important of all fuel saving tips, for the operating engineer knows his own plant better than does anyone else, and his "suggestions to himself" for conserving fuel, *if carried out*, often represent the most important fuel conservation opportunities.

Active volunteer work of the program has been brought to a close, as a result of the findings of the fuel authorities that, with the ending of the war, the fuel situation was no longer serious enough to make it necessary to continue to call on volunteer forces for their help.

This does not, of necessity, mean that there is plenty of fuel now available but rather that fuel conservation is now a peacetime problem.

## 19 Practical Pointers on

# SEPARATING STEAM TRAPS

**1) Why are steam traps used?**—Steam traps are used to remove condensate from steam lines, radiators, and steam heated process units with minimum loss of steam. If there were no steam traps, large quantities of steam would enter the condensate return lines, resulting in great waste of fuel.

**2) What kind of steam traps are there?**—There are two main types of steam traps: Separating traps, which accept condensate at one pressure and discharge it to a lower pressure; and pumping steam traps, which take condensate at low pressure and discharge it against a higher pressure. The discussion in this quiz sheet will be limited to separating traps and whenever the term "steam trap" is used a separating trap will be meant.

**3) Is there more than one kind of separating trap?**—Yes, there are seven different types as follows:

a) *Thermostatic Traps*—in which the discharge valve is controlled by the temperature surrounding a bellows or diaphragm, or by the density of fluid passing through two orifices in series.

b) *Ball Float Traps*—in which the position of the discharge valve is directly controlled by a ball float which rises as condensate enters the trap and falls as condensate leaves the trap. One trap of this type uses a ball float to lift a weight which then falls and opens the discharge orifice.

c) *Float and Thermostatic Traps*—which use a ball float to control the water discharge and a thermostatic element to control the venting of air.

d) *Upright Bucket Traps*—Water spilling into the upright bucket opens the valve. The water is forced out of the bucket through a siphon tube which causes the bucket to float and close the valve.

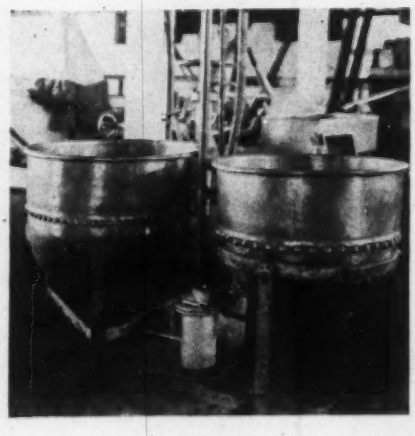
e) *Inverted Bucket Traps*—in which the inverted bucket is completely submerged in water. When full of steam it floats and closes the discharge valve. When water displaces steam, the bucket sinks to open the valve.

f) *Thermodynamic Traps*—in which the temperature of the condensate regulates the rate of flow through the trap orifice.

g) *Tilting Traps*—Incoming water fills the tank to a point where the increased weight of the water overcomes the effect of the counterbalancing lever and weight, allowing the tank to tilt forward and automatically open the discharge valve which allows the water to flow to its point of disposal.

**4) Where should traps be placed?**—In general, traps should be installed below the units that they drain. Traps should be in an accessible location; otherwise, they may be neglected.

**5) Should trap be installed on each steam heated machine or heating unit?**—In general, yes. The practice of draining two or more steam heated units with a single trap is more than likely to result in short circuiting. Air and/or condensate may accumulate in one or more of the machines. Such machines will be below steam temperature and will operate at less than maximum efficiency. These machines must be operated longer to turn out the same amount of work. Nonproductive radiation losses are thereby increased, which, of course, means excess steam consumption, to say nothing of the extra labor cost of operating the machines.



**6) Are your traps properly sized?**—If too much time is required to bring kettles, tanks, heaters, coils, etc., up to temperature, it may be that the traps are too small and have insufficient air handling capacity. Make certain that your traps have sufficient capacity for starting and for peak operating loads. Examine water gages on separators and drip pockets to be sure there is no accumulation of condensate.

**7) Are your steam pressures correct?**—When the steam supply to heating and process units is controlled by a regulating valve, the steam pressure should be checked at regular intervals. If too high, the elements of thermostatic traps may be damaged or mechanically operated traps may not be able to open their valves against the higher pressure. If too low, heating and process units will not get enough steam and traps may not have enough pressure differential.

**8) Do petcocks blow steam?**—Where petcocks are used to prevent air binding, make sure that an absolute minimum of steam is being wasted to the atmosphere.

**9) Do gage cocks or glasses leak?**—Check carefully and replace if necessary.

**10) Are your manually controlled valves passing steam?**—If traps are of the baffle type with manually controlled condensate valve, reduce manual setting to point where no passage of steam occurs.

**11) Do you have correct vacuum in your vacuum return lines?**—See that all parts of thermostatic traps, including cover, tail piece, and union, are tight against back leakage of air.

**12) Do you have a regular schedule for testing traps?**—For maximum efficiency all traps, with the exception of small thermostatic radiator traps, should be equipped with test valves on the down-

stream side of the trap valve to facilitate periodic testing for steam leaks. A "T" or "Y" with a pipe plug can be used in place of a test valve. If the back pressure in the return line is likely to be high, there should be a check valve or shutoff valve in the discharge line to prevent flash steam in the return line from passing through the test valve.

**13) What is the difference between live steam and flash steam?**—Live steam is so called "blue steam" accompanied by little or no condensate, while flash steam is white and will vary with the amount of condensate. Intermittent discharge from a tilting or an upright or inverted bucket trap can be taken as proof that the trap is not leaking steam. Flash from continuous discharge types is fairly constant in volume and white in color.

**14) Do you have a routine inspection schedule for all traps installed in your plant?**—At least once a year all traps should be opened for inspection and cleaned thoroughly and repaired if necessary.

(Note—Do not open a thermostatic trap while it is hot. To do so may ruin the bellows or diaphragm. Many thermostatic traps are installed on heating systems and their inspection should be done in the summertime.)

a) *Is the trap body or mechanism dirty?* Remove all sediment and other dirt from the trap body. Mechanisms may require cleaning by immersing in gasoline or kerosene. If there is an exceptional amount of dirt, it might be advisable to install ahead of the trap a strainer, which will have to be blown down or cleaned at periodic intervals. The presence of an oily paste in the trap body, particularly on traps draining lines supplied with exhaust steam from reciprocating engines, may indicate that the engines are getting an excessive amount or poor grade of oil. Check this point.

b) *Are valves and seats tight?* If the valve seat has a sharp edge and if there is a narrow and shallow bright ring all the way around the valve, the chances are that the valve is making a tight joint with its seat. All valves and seats that have become wire drawn or badly grooved from wear should be replaced with new valve parts that have been properly lapped together. Be sure that the new valve parts are the right size for the trap and the operating pressure.

c) *Is the operating mechanism in good condition?* Cracked or corroded buckets should be replaced. A closed float that is partly filled with water indicates a leak and the float should be replaced. Worn out and inoperative interiors of thermostatic traps should be replaced.

Check the operating mechanism, or leverage system, for smooth operation. Any erratic action should be eliminated by repairing or replacing worn, corroded, or damaged parts.

d) *Is the air venting mechanism in good condition?* If trap buckets are equipped with an auxiliary bimetal thermostatic air vent, make sure that it is functioning properly by immersing in boiling water.

In float and thermostatic traps check the bellows valve and seat.

Replace worn out bellows or worn valve parts.

**15) Are trap bypass valves tight?**—If traps are installed with a bypass it is highly important that the bypass valve be checked to make sure it is perfectly steam tight. If the trap can be operated without the bypass, by all means remove it. Avoid the more or less common practice of opening bypass valves and leaving them open. It wastes a lot of steam.

**16) Are traps in your heating system passing steam?**—Check the temperature of the trap return main and if too high at the pump room or boiler room, trace back along the returns to locate hot runouts from stubs or risers.

**17) Are you wasting flash steam?**—If flash steam from your medium or high pressure traps is being vented to the atmosphere, you are wasting both steam and fuel. Plants with high and medium pressure traps can recover flash steam by one of the following methods:

a) Pass the condensate or flash steam through a heat exchanger such as space heater, water heater, feedwater heater.

b) Discharge the condensate or flash into a nearby low pressure heating main.

**18) Is all condensate reclaimed?**—Loss of condensate by blowing drains to the sewer or atmosphere is exceedingly wasteful. Condensate should be piped back to apparatus requiring hot water or to the boiler through traps or other devices.

**19) Do you have trap manufacturers' catalogs and service bulletins?**—If not, write for them. Manufacturers are glad to furnish data on traps and trap servicing.

## PRESSURE VESSEL RESEARCH ANNOUNCED

A comprehensive pressure vessel research program covering materials, design, fabrication, inspection, and testing of unfired pressure vessels has been started by the Welding Research Council, which is sponsored by the American Welding Society, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and other engineering societies.

This program has been initiated to answer the need for quantitative data by those engaged in pressure vessel design and construction to insure sound design and reasonable life. During the war, experimental work had fallen behind the increased use of both carbon and alloy steels in larger and more complex designs of welded vessels used in process industries under increasingly severe service conditions. The lack of factual information has resulted in acknowledged over-conservatism in design and has hastened the start of the new research program.

*9 Helpful Suggestions About*

# RETURN OR PUMPING STEAM TRAPS

**1) What is the purpose of installing return or pumping traps?** Return or pumping traps, which will be called pumping traps in this sheet from here on, are used for the drainage of all types of steam heating, cooking, drying and evaporating apparatus, whether the equipment is operating under pressure or vacuum, and for the disposal of the water of condensation.

**2) What classes of pumping traps are there?**—There are two main types of pumping traps, float and tilting, both operated by steam pressure directly applied to the surface of the condensate or water in the tank of the trap.

The valves on the float type trap are controlled by means of a float within the stationary tank of the trap. The tank of the tilting trap is entirely or partially supported by a trunnion connected to the tank off center or at one end, the valves being operated by the weight of the water in the tank when the tank goes to a dumping or discharging position.

**3) Where are pumping traps used principally?**—Pumping traps are used for:

a) The elevation of or the pumping of condensate or feedwater from a lower to a higher elevation and discharging it against a pressure.

b) The return of condensation to boilers.

c) The drainage of heating surfaces operating under a vacuum.

**4) How may the condensation be gathered into the tank of a pumping trap?**—There are two general methods of gathering the condensate water into the tank of a pumping trap:

a) The individual trap method, in which the condensation is removed from the heating surfaces by separating traps to a main return line or a receiving tank, from which it is delivered to the pumping trap.

Where the discharge pressure at the separating trap is sufficient, the condensation may be discharged directly to a receiver located at a higher elevation than the boiler feeding trap, which, in turn, is placed at an elevation of at least 4 ft above the water line of the boiler.

In the case of low pressure condensation, a pumping trap is placed below the tank which takes the condensate from the separating trap and discharges it to the tank above the boiler feeding trap, or directly to the boiler feeding trap as circumstances indicate.

b) The group gravity drainage method, in which the water of condensation flows by gravity from the heating surfaces to a receiver placed low enough for the equalization of terminal pressures. The positive equalization of pressures is obtained by placing swing check valves at the receiver and allowing for a column of water on top of the check valves (estimated at ½ lb per ft of elevation) to overcome any differences there may be in terminal pressures.

Where the drip pressures are sufficient to raise the condensation from the receiver to the boiler feed trap, the receiver is equipped with a siphon connection for the delivery of the water to the boiler feeder. (This pressure is estimated at ½ lb per ft of elevation.)

When the boiler feeding trap has accumulated a sufficient amount of water to overcome the counterweight of the trap or have the float to a certain position, a direct steam connection is opened from the boiler, allowing boiler pressure steam to enter the tank on top of the water, thus equalizing the pressure on the water in the tank of the trap with the boiler pressure, and the water flows by gravity through the check valves into the boiler.

**5) What is the vacuum type pumping trap and where is it used?**—The vacuum type trap is used for the drainage of heating surfaces operating under a vacuum. The device differs from the standard pumping trap in that it is equipped with a larger relief valve which is connected directly back into the vacuum line for the equalization of the vacuum which allows the condensation to flow by gravity from the heating surfaces to the trap which is placed at a lower level than the surface drained.

**6) What is the condenser type pumping trap?**—This trap differs from the standard pumping trap in that it is equipped with a connection for the use of a spray or jet of cold water for condensing the steam left in the tank of the trap after the trap has discharged. This device is especially adapted to the drainage of heating surfaces where the circulation is slow.

**7) Where should pumping traps be located?**—In general, traps in drainage service should be installed below the units that they drain. The traps should be in a dry, accessible place. Otherwise, the maintenance man may neglect them.

Traps used in boiler feeding service are installed at least 4 ft above the water level in the boiler and located near the boiler in an accessible place.

**8) Are your pumping traps properly sized?**—If too much time is required to bring kettles, tanks, heaters, coils, etc., up to temperature, it may be that the traps are too small. Make certain that your traps have sufficient capacity for starting and for peak operating loads. Examine water gages on separators and drip pockets to be sure that they indicate no accumulation of condensate.

**9) Do you have a regular schedule for inspecting pumping traps?**—It is important that traps be inspected at regular intervals and cleaned thoroughly and repaired if necessary.

# RECENT TRADE LITERATURE

**For your convenience in obtaining copies of these bulletins, see coupon on page 167. If you write direct to the manufacturer, describe carefully what literature you want, as the number given first in each item is for use only when sending in your request to Heating, Piping & Air Conditioning.**

### Air Conditioning and Refrigerating Equipment

No. 6068—The Frick Co., Waynesboro, Pa., has published a new 32 page bulletin (80-B) which illustrates and describes the company's line of refrigerating, ice-making, and air conditioning equipment. Low pressure units from ¼ to 15 hp for "Freon-12" or methyl chloride, "Eclipse" compressors from 25 to 50 hp for "Freon-12," combined ammonia units, enclosed ammonia compressors, booster compressors, and large 4 cylinder compressors are covered. Also included are condensers, coolers and coils, control equipment, valves, and fittings. The various basic types of air conditioning systems and examples of several refrigerating installations are cited in this bulletin.

### Air Distribution Panels

No. 6069—The preliminary engineering manual, of some 40 pages and in mimeograph form, which was issued some months ago by the Multi-Vent Div. of the Pyle-National Co., 1334 N. Kostner Ave., Chicago 51, Ill., has been revised by the addition of some 40 odd illustrations, additional test data, and revisions to explanatory material. These panels, which are designed for "uniform, no draft" introduction of air in heating, ventilating, and air conditioning systems, are described and illustrated. Technical data pertaining to the selection, use, and installation of these panels are included.

A 4 page bulletin (Form No. 380-A), which illustrates and describes the features of these panels, has also been released.

### Automatic Clutch

No. 6070—Designed for operating loads up to 6 hp, an automatic clutch of the opposed shoe type, which is dual-spring-balanced and which utilizes centrifugal force, is described in a 4 page bulletin (No. 4501) issued by Salsbury Motors, Inc., 4464 District Blvd., Los Angeles 11, Calif.

### Bearing Alloys

No. 6071—The history and some significant developments in bearing alloys, the melting and casting of bearing alloys, together with the effect of composition, the bonding of bearings and the causes of bearing failure are among the subjects discussed in a 34 page booklet, Bearing Alloys Technical Manual, published by Federated Metals Div., American Smelting and Refining Co., 120 Broadway, New York 5, N. Y. In addition to this booklet, which was prepared to assist in the design, construction, and maintenance of friction bearings, the company is also offering (at no charge) a cardboard slide rule designed to indicate melting points for 98 tin-lead solder alloys. The reverse side of the device gives comparisons, in inches, of wire gage from 0000 to 40.

### Bronze Pipe Fittings

No. 6072—A 17 page catalog illustrating the company's line of "Flaggseal" cast bronze fittings has been issued by Stanley G. Flagg & Co., 1421 Chestnut St., Philadelphia 2, Pa. For making "Silbraz" joints in piping systems of IPS brass or copper pipe, or copper tubing, a ring of silver brazing alloy is incorporated in the port opening of each fitting. The application of heat by an oxy-acetylene flame causes the alloy to melt and flow between the pipe wall and the bore of the fitting, thus sealing the joint.

Permissible pressures and temperatures together with dimensions are given for this company's extensive line of standard and extra heavy fittings, and other pertinent data such as various combinations of threaded outlets, flanged and union ends, together with instructions for making this type of joint, are included.

### Controlling, Recording, and Indicating Instruments

No. 6073—A new 24 page general catalog (Bulletin W1800) has been published by the Bristol Co., P. O. Box 1790, Waterbury 91, Conn. The company's lines of automatic controlling, recording, and indicating instruments are covered and specification data are given on each instrument listed. Basic application methods and recommendations for efficient operation of the instruments are included.

### Design of Radiant Heating Systems

No. 6074†—Offered "with the hope and expectation that it will enable engineers and architects familiar with the design of conventional heating systems to more properly appreciate the advantages and limitations of radiant heating and the procedure necessary in designing a radiant system," a manual on the subject has been published by the Chase Brass & Copper Co., 236 Grand St., Waterbury 91, Conn., and is now available. The price is $3.00.

Divided into five principal parts, this comprehensive book should be a welcome addition to the shelves of those interested in this subject. The text and supplementary charts provide simplified solutions for many types of installations and practical installation pointers, together with a considerable discussion of the theory of heat transfer, the derivations of formulas used, and the assumptions made in constructing the charts are included.

By way of introduction, the text defines radiant heat, offers a brief history of its development, and discusses the fundamental principles with respect to establishing body heat balance. The advantages of this type of heating, basic requirements of panels, and calculations to demonstrate that allowable unit stresses in copper tubing and in the cohesive bond are not exceeded when this

†For copies of this manual write directly to the manufacturer. Do not send requests to Heating, Piping & Air Conditioning.

tubing is imbedded in concrete, are included in the introductory section.

In the basic design procedure set forth, the preliminary steps consist of determining the room heat losses by conventional methods, selecting the panel location from a study of the general dimensions of the room, exposures, and occupancy, and determining the available area for panels. The minimum Btu output per square foot of panel together with the mean equivalent temperature (which is taken as the average of the room air temperature and the mean surface temperature of all unheated room enclosures) are used to determine, from charts, the required mean heating panel temperatures. Additional charts are provided for determining the required tube diameter and spacing for various combinations of mean panel temperature and assumed water temperatures. Other charts are included for finding the Btu loss or reverse directional heat transfer of panels. These data are used to establish the total Btu loss of panels, the rate of water flow, and the pump capacity. This method is applicable for rooms having natural ventilation or where air is introduced at approximately the comfort temperature.

Part 5 of this manual has been written for those cases where the air temperature desired is well above (or below) the comfort temperature and for those who are interested in the theory of radiant heat transfer. Fundamental equations of heat exchange, a brief review of the literature, and test results of various investigators are included. The derivation of the foregoing simple approximate method and the assumptions made are set forth. Among the assumptions for this graphical method are (1) $C_r$ (emissivity constant) $= 4.4$, (2) $\beta$ (convection transfer coefficients) according to the values of Nusselt, (3) the comfort, mean equivalent, room air, and mean surface temperature of all unheated room enclosures are equal.

The rational method, which is recommended for rooms with forced ventilation, is considerably more involved than the graphical solution method. It involves assumptions for the mean surface temperatures of heating, neutral, and heat dissipating panels together with assumptions for air temperature and mean radiant temperature. Form factors and a conduction coefficient are computed and a heat balance for the room is set up which requires the solution of three simultaneous equations. To reduce errors caused by the assumptions, three approximations are recommended.

Heat loss coefficients of transmission for various building materials and types of construction have been reprinted from the ASHVE Guide, dimensions and friction loss data for various fittings, and other pertinent information are included in this manual.

### Piping Materials, Fittings, and Fabrication

No. 6075—The December issue of Valve World, published by the Crane Co., 836 S. Michigan Ave., Chicago, Ill., contains an article, Improved Steels for High Pressure-Temperature Power Piping. The author, J. J. Kanter, is chairman of the project appointed to study graphitization of piping steels by the ASTM and ASME joint research committee on the effect of temperature on the properties of metals. The graphitization difficulty in carbon-moly steels, effects of aluminum "killing," and the addition of chromium and vanadium in steel are discussed.

A paper on the selection of piping joints, by G. W. Hauck, discusses the relative advantages and limitations of screwed, screwed flanged, and various types of welded joints. In another article, by W. H. Goetz, the advantages of shop fabrication for piping and valve units are discussed.

### Pressure Regulating Valves, Separators, and Strainers

No. 6076—Direct operated and pilot operated pressure regulating valves of the spring loaded type, which are designed for steam, air, and gas service, are featured in a new catalog (No. 155) issued by Strong, Carlisle & Hammond Co., 1392 W. Third St., Cleveland 13, O. Features of construction, dimensions, capacities, and parts price lists are included. A new line of fabricated steel separators (for steam, air or gas), together with traps, which may be used for automatic drainage of separators, is also covered.

### Radiant Panel Heating System

No. 6077—A Ratings and Installation Guide for the new "Base-Ray" radiant baseboard, illustrated with 25 drawings and photographs, has been published by the Burnham Boiler Corp., Main St., Irvington, N. Y. Tabulated ratings are included for both the standard and the "Hy-Power" models of this type panel. While the heating system is installed in much the same manner as any radiator system, pertinent recommendations for insulating, venting, expansion, supporting brackets, and other special features are included.

### Recording and Indicating Instruments

No. 6078—The Foxboro Co., 106 Neponset Ave., Foxboro, Mass., has issued a new catalog (No. 370) illustrating and describing the company's line of recording and indicating instruments for measurement and control. Instruments for temperature applications, pressure, humidity, flow, liquid level, density and other process variables are covered. This catalog is the first in which the company's line of "Dynalog" electronic instruments is described.

### Steam and Fluid Traps, Valves, Separators, and Strainers

No. 6079—Steam and fluid traps of the inverted bucket, open bucket, thermal, and float types for low, medium, and high pressure together with traps for vacuum or low pressure lines are described and illustrated in a 60 page catalog (No. C-45) published by the Clark Mfg. Co., 1830 E. 38th St., Cleveland 14, O. Capacities, dimensions, pipe connection sizes, parts price lists, and data for sizing and selecting the units are included. Also described are pressure reducing and regulating valves, strainers, separators, globe valves, and orifice blocks.

### City Rules Against Direct Connection From Water Mains to Condensers

Based on sections of the municipal code in effect for several years—but not heretofore enforced insofar as refrigeration and air conditioning are concerned—the Chicago water pipe extension division has ruled against the direct connection of a condenser to a city water main. The installation of a surge tank with an open connection is suggested to provide a break between the main and the condenser.

According to city authorities, there have been several cases of complaints of refrigerant in water mains, and in one instance ammonia was found in the mains and in the plumbing distribution systems in nearby buildings. This was traced to a leak in a condenser tube which had been in service only a year.

There is considerable opposition to the ruling from engineers and contractors who feel it is unnecessary as a safety measure, and who point out that—under the ruling—not only is a tank required, but a pump and controls are also necessary. It is also stated that the only cases causing trouble have been "illegal" in that there were shutoff valves on the condenser water outlets, allowing leaking refrigerant to back up into the mains.

The situation is further complicated by a jurisdictional dispute, and a difference of opinion on the part of two city departments concerned as to whether open or gastight tanks shall be used.

### AGA Conference to Be Held March 29 and 30

The American Gas Association conference on industrial and commercial gas, originally scheduled for March 28 and 29, has been moved one day to Friday and Saturday, March 29 and 30. It will be held in Toledo, Commodore Perry hotel, as previously announced.

### Samuel R. Lewis to Speak on Air Conditioning Fundamentals

The Air We Live In will be the subject of a talk by Samuel R. Lewis, member and past president of ASHVE, scheduled for March 31 at the main auditorium of the Chicago Museum of Science and Industry. His talk, sponsored by the Illinois chapter of ASHVE, will be one of a series of popular Sunday afternoon lectures under the joint direction of the museum and the Chicago Technical Societies Council.

### Midwest Power Conference Program to Include Heating and Air Conditioning

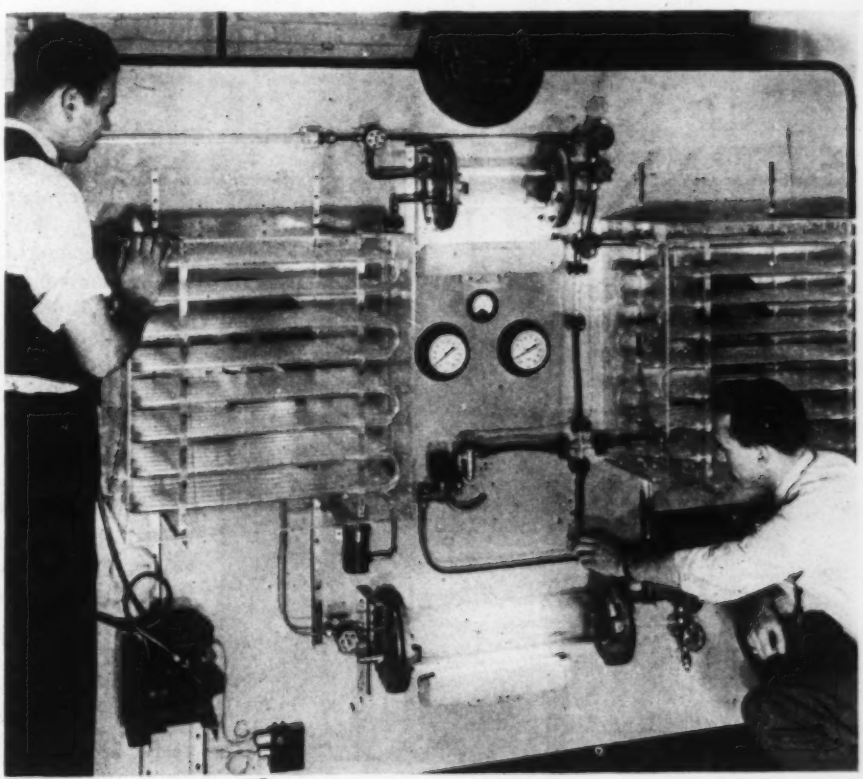
The Midwest Power Conference, which will be held April 3-5 at the Palmer House, Chicago, is being sponsored by the Illinois Institute of Technology in cooperation with a number of midwestern colleges and universities and several engineering societies. According to the program, the session on developments in air conditioning will be held at 2:00 p.m. Wednesday, April 3, during which a paper on Centrifugal Compressors and one on Cooling Tower Selection will be presented by W. H. Carrier, chairman of the board, Carrier Corp., and J. Lichtenstein, Foster Wheeler Corp., respectively. At 3:30 p.m., in the session on feedwater treatment, Leo F. Collins, Detroit Edison Co., will discuss Problems in Water Conditioning in Plants using High Percentages of Makeup. During the session on developments in space heating, which is scheduled for 9:00 a.m. Thursday, April 4, a paper on Radiant Heating will be presented by T. Napier Adlam, vice-president, Sarco Mfg. Co., Inc., and one on Industrial Applications of the Heat Pump will be read by Philip Sporn, vice-president, American Gas & Electric Service Corp.

The conference secretary, C. A. Nash, Illinois Institute of Technology, 3300 Federal St., Chicago 16, Ill., requests that advance registration be made by mail.

## *VETERANS GET AIR CONDITIONING TRAINING*

**To meet the need of a thorough educational program in engineering, production, sales, service, and factory management for its employees and its returning veterans, York Corp. formally opened last month an institute of refrigeration and air conditioning. The school has a potential capacity of 1000 students annually, and will provide courses ranging in duration from a five year cooperative engineering course, run in conjunction with Pennsylvania State College, to a two week "refresher" course.**

**A transparent refrigeration system —part of the institute's equipment— traces compression refrigeration through its complete cycle. The student can actually see the tranformation of gas to liquid and back to gas again as the refrigerant flows through the system evaporator and condenser**



# Court Orders Dedication of Air Conditioning Patents to Public

A CONSENT decree signed by a federal judge December 28 directs dissolution of the Auditorium Conditioning Corp., and dedication of its air conditioning patents to the public. The decree was sanctioned by five manufacturers who, according to the government, controlled 90 per cent of the manufacturing, distribution, and sales in the air conditioning industry.

Following is a listing of these patents, the grouping and titles being for convenient reference and not to define or limit the scope or coverage of the patents referred to:

*Group A . . . Bypasses External to Conditioner . . . Physical Bypass*

1. Standard Bypass—U. S. Patent Reissue 20088.
2. Fresh and Mixed Air Bypass—U. S. Patent 1977315.
3. Mixed Air Bypass—U. S. Patent 1895444.
4. Fixed Bypass—Variable Conditioning—U. S. Patent Reissue 20944.
5. Remote Bypass—Local Recirculation—U. S. Patent 1983023.

*Group B . . . Bypasses Internal to Conditioner . . . Bypass Effect*

Sprays

1. Sprays Across Washer—Coil Across Lower Half—U. S. Patent 2110203.
2. Wet Coils to Control Constant Differential Between Washer Ends—U. S. Patent 2110164.
3. Stratified Dehumidification—U. S. Patent 1955406.
4. Controlled Spray Dehumidification—U. S. Patent 1846875.

Water, Brine or Direct Expansion Coils

5. Coils Across Conditioner Variably Controlled—U. S. Patents 2009529; 2202946.
6. Coils in Series with Air Flow—Variably Controlled—U. S. Patent Reissue 20069.
7. Single Coil Across Conditioner—Refrigerant Controlled—U. S. Patent Reissue 21946.
8. Damper Coils to Produce Variable Conditioning—U. S. Patents 2105692; 2150505.

*Group C . . . Differential Controls*

1. Designed for Economical Refrigeration—U. S. Patent 1840565.
2. Designed for Maximum Use of Outside Air—U. S. Patent 1751805.
3. Maximum and Minimum Inside Based on Outside Air—U. S. Patent 1751806.

*Group D . . . Dehydration**

1. With Cooling of Outside Air and Drying of Mixed Air—U. S. Patent 1863579.
2. With Separate Treatment of Outside and Mixed Air—U. S. Patent 1863578.
3. With Separate Treatment of Outside and Return Air—U. S. Patent 1863577.
4. With City and Chilled Water Cooling—U. S. Patent 1863576.
5. For Summer Cooling with Return Air Bypass—U. S. Patents Reissue 17998; 2213350.
6. For Year Round Use—U. S. Patent Reissue 18831.

*Group E . . . Miscellaneous*

1. Discharge of Conditioned Air Enveloped by Return Air—U. S. Patent 2131725.
2. Horizontal Discharge of Conditioned Air Supported by Layer of Room Air—U. S. Patent 2112685.
3. Lobby and Waiting Room System—U. S. Patent 1817384.
4. Two Stage Conditioner—U. S. Patent 1718815.
5. Air Diffuser for Auditorium — U. S. Patent 1737661.
6. Reheat with Condenser Cooling Water—U. S. Patent 1902563.
7. Regulating Volume and Direction of Air Discharge Responsive to Conditions in Enclosure—U. S. Patent 2259780.
8. Increasing Reduction of Latent Heat of Air while Decreasing Reduction of Sensible Heat—U. S. Patent 2249856.

*Dehydrator may be silica gel, lithium chloride, or similar substances.

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**Irving Krushel, author of the article Electronic Tube Chemicals Need Clean Air in our March 1945 issue, stirs a batch of chemicals in the steam heated, glass lined kettle at the Dobbs Ferry, N. Y., phosphor laboratory of North American Philips Co., Inc. These important ingredients that go to make cathode ray tube screens must be kept absolutely pure. For this reason, the laboratory is segregated from the factory proper. Dust and impurities in the atmosphere are removed by means of electrostatic precipitation. The large tank on the left produces distilled water which is also needed in the phosphor mix that is used in this process**

Heating, Piping & Air Conditioning

AMERICAN SOCIETY of HEATING and VENTILATING ENGINEERS

Journal Section

# Low-Pressure Properties of Water from –160 to 212 F

By John A. Goff* and S. Gratch,** Philadelphia, Pa.

## Introduction

IN CONNECTION with a cooperative investigation into the thermodynamic properties of moist air, between the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS and the Towne Scientific School, University of Pennsylvania, it became necessary to examine critically available data on the properties of water itself. In this country the accepted source of information regarding the thermodynamic properties of water is the Keenan-Keyes steam tables[1] published in 1936, hereinafter referred to as *the steam tables*. Critical examination of the data given in these tables revealed that they do not possess a very high degree of accuracy at temperatures below 212 F; hence, an attempt to improve them in this range became necessary. The present paper outlines this attempt at improvement and offers important revisions to Table 1, Saturation (liquid-vapor), in the range 32 to 212 F, and to Table 5, Saturation (solid-vapor). The range of Table 5 has been extended downward to –160 F.

The present paper is offered as a contribution from the University of Pennsylvania Thermodynamics Research Laboratory recently established at the University of Pennsylvania with the active support of the Navy Department, Bureau of Ships.

## Saturation Pressure

In order to achieve accuracy in the formulation of the thermodynamic properties of moist air, as published in a recent paper,[2] it was especially important to have accurate information regarding the saturation pressure $p_s$ and of the second virial coefficient $A_{ww}$ of water as functions of absolute temperature $T$. The coefficient $A_{ww}$ appears in the equation,

$$pv = RT - A_{ww}p \quad \ldots\ldots\ldots (1)$$

valid at sufficiently low pressures $p$. At temperatures below about 150 F, this equation appears to be valid from zero pressure to saturation pressure; accordingly, it is accurate to write

$$p_s v_g = RT - A_{ww}p_s \quad \ldots\ldots\ldots (2)$$

at these temperatures. Using the value of $RT_o$, namely, 22414.6 ± 0.6 (cm³atm/mole) recommended by Birge[3] (1941), where $T_o$ denotes ice-point temperature, also using what appears to be the best value for the molecular weight of water, namely, 18.0160 (lb/mol), the value,

$$A_{ww}p_s = 24 \pm 42 \quad \text{(ft)}$$

is readily computed from values of $p_s$ and $v_g$ listed in the steam tables at 32 F. The uncertainty ±42 (ft) is that produced solely by the tolerance of ±0.1 per cent assigned to the saturation pressure at 32 F by the Third International Conference on Steam Tables.[4]

At 158 F, the tolerance assigned to the steam table value of saturation pressure is only ±0.05 per cent. Using the value of $T_o$ recommended by Birge,[3] namely, 273.16 ± 0.01 K, and assuming a linear relation between absolute temperature $T$ and international centigrade temperature $t$, the value,

$$A_{ww}p_s = 377 \pm 26 \quad \text{(ft)}$$

is readily computed from values of $p_s$ and $v_g$ listed in the steam tables at 158 F. Again the uncertainty of ±26 (ft) is that produced solely by the tolerance assigned to the

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[1]Exponent numerals refer to Bibliography.

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saturation pressure.

The foregoing calculations make it clear that, if the accepted tolerances in the steam table values of saturation pressure were the only source of uncertainty, fairly satisfactory values of second virial coefficient $A_{ww}$ might be obtained from steam table data for the higher temperatures, but not for the lower.

### Saturated-Vapor Volume

Steam table values of the specific volume of the saturated vapor $v_g$ were computed from the empirical equation of state constructed by Keyes, Smith, and Gerry[5] to fit their experimental $p,v,t$-data in the range 195 to 460 C. The extrapolation to temperatures below 212 F must be expected to introduce considerable uncertainty. Indeed, Collins and Keyes[6] have found discrepancies of about 15 per cent at 104 F, 15 per cent at 140 F, 6 per cent at 212 F, between their measured values of the coefficient $(\partial h/\partial p)_T$ and corresponding values computed from the Keyes, Smith, and Gerry equation of state by means of the thermodynamic identity,

$$(\partial h/\partial p)_T = (\partial v_T/\partial_T)_p \quad \ldots\ldots (3)$$

where $_T$ denotes reciprocal absolute temperature. In view of these discrepancies, uncertainties of at least $\pm 0.04$ per cent at 104 F, $\pm 0.08$ per cent at 140 F, $\pm 0.10$ per cent at 212 F, must be assigned to the steam table values of $v_g$.

From the previous calculations it seems fair to conclude that the uncertainty in the steam table values of vapor volume $v_g$ is of the order of $\pm 0.10$ per cent over most of the range 32 to 212 F. This greatly reduces the reliability of values of $A_{ww}$ computed directly from steam table data.

### Saturated-Vapor Enthalpy

The steam table values of saturated-vapor enthalpy $h_g$ were obtained by computing the coefficient $(\partial h/\partial p)_T$ from the Keyes, Smith, and Gerry equation of state by means of the thermodynamic identity Equation (3), integrating this coefficient from zero pressure to saturation pressure $p_s$, and adding values of zero-pressure enthalpy calculated by Gordon[7] from the spectroscopic data of Mecke[8] and coworkers. But Gordon's values are probably in error by as much as 0.5 Btu per lb in part of the range 32 to 212 F because he neglected to include the effect of centrifugal distortion of the water molecule in his calculations. Newer spectroscopic data and recent revisions in the fundamental physical constants (Planck's constant $h$, Boltzmann's constant $k$, Avogadro's number $N_o$) suggest an even greater probable error. Furthermore, as explained previously (Saturated-Vapor Volume), the values of $(\partial h/\partial p)_T$ derived from the Keyes, Smith, Gerry[5] equation of state are not very reliable, and contribute to a probable error of at least 0.3 Btu per lb at 212 F.

The cumulative probable error in the steam table values of saturated vapor enthalpy $h_g$ can be estimated by comparing the steam table value 1075.8 Btu per lb with the value $1075.1 \pm 0.1$ Btu per lb given by Osborne, Stimson, and Ginnings[9] for 32 F.

### Other Properties

Steam table values of saturated vapor entropy $s_g$ are probably no more reliable than those of saturated vapor enthalpy $h_g$; those of saturated liquid volume $v_f$ in the range 32 to 212 F are probably more than sufficiently accurate for all practical purposes; those of saturated liquid enthalpy $h_f$ and of saturated liquid entropy $s_f$ are also quite accurate but should be revised in the light of more recent, extremely accurate, Bureau of Standards values.[9]

Values listed in Table 5 of the steam tables are entirely inadequate both as to accuracy and as to range. This table should be reformulated and extended to cover a much wider range of temperature from 32 F downward.

### Zero-Pressure Properties of Water Vapor

Mecke and coworkers[8] were the first fully to analyze the rotation-vibration spectrum of the water molecule. Their results have since been extended and improved by the use of theoretically more rigorous analytical methods. The best information presently available is that of Randall, Dennison, Ginsburg, and Weber,[10] of Darling and Dennison,[11] and of Nielson.[12] These investigators have analyzed higher rotational levels than did Mecke and have taken account of such effects as centrifugal distortion and certain perturbations between vibrational levels, which effects had been neglected by Mecke.

Gordon[7] calculated the zero-pressure properties of water vapor from the spectroscopic data of Mecke and coworkers[8] using the now obsolete values of the fundamental physical constants given in *International Critical Tables*. Wilson[13] called attention to the fact that Gordon had neglected to take account of the centrifugal distortion of the water molecule and estimated a correction for this effect to be applied to Gordon's values. Stephenson and McMahon[14] calculated this correction for temperatures below 300 K directly from the newer spectroscopic data of Randall, Dennison, Ginsburg, and Weber[10] and found agreement as to form, but slight disagreement as to magnitude, with Wilson's estimate. To obtain accurate values of the zero-pressure properties, especially at the higher temperatures, clearly calls for a systematic recalculation based on newest spectroscopic data and best values of the fundamental physical constants.

Recently the *American Society of Mechanical Engineers* has authorized the formation of a Special Research Committee on Gas Properties which will undertake to assemble information regarding the thermodynamic properties of gases and gas mixtures of sufficient accuracy to warrant acceptance as standard. Undoubtedly this Committee will want to sponsor the systematic recalculations referred to above.

The temperature range of interest in the present paper extends only from 100 to 400 K. Throughout this range true equilibrium between the *ortho* and *para* modifications of the water molecule is always attained so that the composition of ordinary water as a mixture of these two modifications is fixed and definite. Also, in this range the rotational levels are fully excited, according to Stephenson and McMahon, and small changes

in the vibrational levels from those used by Gordon, as well as certain perturbations neglected by him, do not affect the final results appreciably. Finally, in this range the correction for centrifugal distortion as determined by Stephenson and McMahon is sufficiently accurate.

In the present paper only the variations with temperature, not the absolute values of enthalpy and entropy are of interest because the usual steam-tables practice of assigning each the value *zero* for saturated liquid at 32 F is to be followed. Since the rotational levels are fully excited in the temperature range considered, small changes in the rotational constants from those used by Gordon would alter the calculated values of enthalpy and entropy by constant amounts only and may therefore be ignored.

In view of these circumstances, sufficiently accurate values of zero-pressure enthalpy and reduced entropy can be obtained from the Gordon data by correcting them for changes in the fundamental physical constants and for the effect of centrifugal distortion. The most satisfactory procedure is first to construct a semi-theoretical control equation whose constants can be adjusted to fit the Gordon data, then to revise these constants as required by changes in the fundamental physical constants, finally to add the correction for centrifugal distortion. From the resulting formula the zero-pressure properties of interest can be calculated at as close intervals of temperature as desired.

Analysis of the spectrum of a molecule determines a set of discrete energy levels $\epsilon_l$ representing the only energy values the molecule can assume in its various modes of internal motion—rotational, vibrational, electronic, nuclear. Actually, the wave numbers $\nu_l$ not the energy levels themselves, are the quantities directly measured; but these are related by the simple formula, $\epsilon_l = hc\nu_l$, where $h$ denotes Planck's constant and $c$, the speed of light. The sum over all internal quantum states (more than one distinct quantum state may have the same energy level) of the quantity $e^{-\epsilon_l/kT}$ is called the *internal partition function* and is denoted by $Q_{int}$.

If the water molecule were a rigid rotator whose atoms vibrate about their equilibrium positions with such small amplitude as to be sensibly harmonic and not to alter the moment of inertia of the molecule appreciably, the complete partition function $Q$, which includes a factor representing the contribution from translational motion, would be given by the expression,

$$lnQ = -3ln\tau + \sum_{j=1}^{i} ln\left(\frac{e^{\theta_j\tau}}{e^{\theta_j\tau}-1}\right) + b\tau + c \quad \ldots\ldots\ldots\ldots (4a)$$

provided the rotational levels are fully excited, as is the case at temperatures above 100 K. The constants $b$ and $c$ are to be regarded as adjustable, but the *characteristics temperatures* $\theta_j$ are to be calculated from the measured fundamental vibrational *frequencies* $\omega_j$ as follows:

$$\theta_j = (hc/k)\omega_j \quad \ldots\ldots\ldots\ldots (4b)$$

Actually, the atomic vibrations in the water molecule are not of sufficiently small amplitude to be regarded as harmonic; but the effect of anharmonicity itself can be accounted for approximately by reducing each characteristic temperature by amount,

$$(hc/k)2\omega_j x_j \quad \ldots\ldots\ldots\ldots (4c)$$

while the accompanying effect of changing the mean moment of inertia can be accounted for approximately by adding to $lnQ$ the sum,

$$\sum_{j=1}^{i} a_j e^{-\theta_j\tau} \quad \ldots\ldots\ldots\ldots (4d)$$

In these expressions, the $x_j$ and $a_j$ are small fractions obtainable from spectrum analysis.

In order to recover Gordon's values of the various zero-pressure properties, it is necessary suitably to adjust the constants $\theta_j$, $a_j$, $b$, and $c$ because of the approximate nature of the corrections (4c) and (4d). Since zero-pressure specific heat $c_p^\circ$ is derived from the complete partition function $Q$ by

$$c_p^\circ = R\tau^2 \frac{d^2 lnQ}{d\tau^2} \quad \ldots\ldots\ldots (5a)$$

it contains neither $b$ nor $c$. Accordingly, the $\theta_j$ and $a_j$ were adjusted by least squares to fit Gordon's values of $c_p^\circ$ in the range 298.1 to 1500 K with a root mean square deviation of 0.0010 and a maximum deviation of 0.0027. In Column 1, Table 1, are listed the adjusted values while in Column 2 are listed the values calculated from the spectroscopic data used by Gordon, for comparison.

The zero-pressure *mean* specific heat $(h^\circ - \tilde{u})/T$, where $\tilde{u}$ denotes null-point energy, is derived from $Q$ by

$$\frac{h^\circ - \tilde{u}}{T} = -R\tau \frac{dlnQ}{d\tau} \quad \ldots\ldots (5b)$$

and therefore contains $b$, but not $c$. Least squares adjustment of $b$ to fit Gordon's values of mean specific heat in the range 298.1 to 1500 K gave a root mean square deviation of 0.0006 and a maximum deviation of 0.0012.

Finally, the zero-pressure reduced entropy $(s + Rlnp)^\circ$ is derived from $Q$ by

$$(s + Rlnp)^\circ = (h^\circ - \tilde{u})/T + RlnQ \quad \ldots\ldots (5c)$$

and therefore contains both $b$ and $c$. With the former already adjusted, least squares adjustment of the latter gave a root mean square deviation of 0.0004 and a maximum deviation of 0.0007 for the range 298.1 to 1500 K.

In making the above adjustments Gordon's values of $R$(1.9869) and of $hc/k$(1.4324) were used, while the final calculations are to be based on $R = 1.98581$ and $hc/k = 1.43848$. The change in $R$ is made in an obvious manner; that in $hc/k$ is accomplished by multiplying each $\theta_j$ by the ratio $1.43848/1.4324 = 1.00424$, leaving the $a_j$ unchanged. Column 3, Table 1, lists the revised values.

**Table 1—Spectroscopic Constants**

| Column | 1 | 2 | 3 |
|---|---|---|---|
| $\theta_1$ (°R) . | 4124.09 | 4111.2 | 4141.6 |
| $\theta_2$ (°R) . | 9317.47 | 9279.0 | 9356 |
| $\theta_3$ (°R) . | 9802.06 | 9682.2 | 9844 |
| $a_1$ ..... | — 0.03958 | — 0.0477 | — 0.03958 |
| $a_2$ ..... | 0.05353 | 0.0321 | 0.05353 |
| $a_3$ ..... | 0.04000 | 0.0342 | 0.04000 |

The foregoing discussion explains the method used to correct Gordon's data for changes in the physical constants and to interpolate them to close intervals of temperature. There remains only to add the respective corrections of Stephenson and McMahon for the effect of centrifugal distortion, all of

**Table 2—Zero-pressure Properties of Water Vapor**

| $t$(F) | $h^\circ$ Btu/lb | $(s+Rlnp)^\circ$ Btu/lb$R$ |
|---|---|---|
| — 288 | 933.86 | 1.1586 |
| — 272 | 940.92 | 1.1979 |
| — 256 | 947.98 | 1.2340 |
| — 240 | 955.05 | 1.2674 |
| — 224 | 962.11 | 1.2984 |
| — 208 | 969.18 | 1.3274 |
| — 192 | 976.24 | 1.3546 |
| — 176 | 983.31 | 1.3803 |
| — 160 | 990.38 | 1.4045 |
| — 144 | 997.45 | 1.4275 |
| — 128 | 1004.52 | 1.4494 |
| — 112 | 1011.59 | 1.4702 |
| — 96 | 1018.66 | 1.4901 |
| — 80 | 1025.73 | 1.5091 |
| — 64 | 1032.81 | 1.5274 |
| — 48 | 1039.89 | 1.5449 |
| — 32 | 1046.97 | 1.5618 |
| — 16 | 1054.06 | 1.5780 |
| 0 | 1061.15 | 1.5937 |
| 16 | 1068.24 | 1.6089 |
| 32 | 1075.34 | 1.6236 |
| 48 | 1082.45 | 1.6378 |
| 64 | 1089.56 | 1.6516 |
| 80 | 1096.68 | 1.6650 |
| 96 | 1103.81 | 1.6780 |
| 112 | 1110.95 | 1.6907 |
| 128 | 1118.10 | 1.7030 |
| 144 | 1125.26 | 1.7150 |
| 160 | 1132.43 | 1.7268 |
| 176 | 1139.62 | 1.7382 |
| 192 | 1146.81 | 1.7494 |
| 208 | 1154.02 | 1.7603 |
| 224 | 1161.25 | 1.7710 |

which are derivable from the correction to $lnQ$, namely,

$$1.29 \times 10^{-5}T \ (T \text{ in } ^\circ R) \quad \ldots . (5d)$$

Table 2 is a skeleton table giving final values of zero-pressure enthalpy $h^\circ$ and reduced entropy $(s + Rlnp)^\circ$ based on saturated liquid at 32 F as reference point for both enthalpy and entropy.

## Properties of Saturated Liquid

We believe that the most reliable tabulation of properties of liquid water is that of Osborne, Stimson, and Ginnings.[9,15] These investigators arranged to add energy electrically to an adiabatic calorimeter containing water in both liquid and vapor phases to ($\alpha$) measure the resulting temperature rise, ($\beta$) maintain temperature constant by simultaneous withdrawal of saturated liquid, ($\gamma$) maintain temperature constant by simultaneous withdrawal of saturated vapor.

Thermodynamic analysis shows that what were measured in the $\alpha$-experiments are increments of the quantity.

$$\alpha = h_t - Tv_t(dp_s/dT) \quad \ldots (6)$$

for measured increments of international centigrade temperature $t$. From the results obtained were derived two empirical equations expressing the dependence of $\alpha$ on temperature $t$, namely,

$$\alpha = \alpha_0 + 4.1699t + 7.635 \times 10^{-6}t^2 + 0.5634(1 - 10^{-0.301t}) \quad \ldots (7a)$$

$$\alpha = \alpha_0 + 0.4858 + 4.17144t \quad \ldots . (7b)$$

the first being valid in the range 0 to 100 C, the second, in the range 100 to 130 C. The unit of $\alpha$ in each is the international joule per gram (int.j/g).

Values of the specific volume of the saturated liquid $v_t$ are given with great accuracy in the Bureau of Standards tables,[9,15] and sufficiently accurate values of the derivative $dp_s/dT$ can be obtained from the unpublished formula of Harold T. Gerry used by the Third International Conference on Steam Tables, namely,

$$\log_{10}p_s = -8.420798\ (T_s/T - 1) + 8.2\ \log_{10}(T_s/T) - 0.92559\ (1 - T/T_s) \quad \ldots . (8)$$

*where* $T = t + 273.16$ and $T_s = 373.16$. Equation (8) will be referred to as the NBS saturation pressure.

Values of the specific enthalpy of the saturated liquid $h_t$ were calculated from the information discussed in the two preceding paragraphs. There is no direct indication in the Bureau of Standards reports[9,15] whether the unit of $\alpha$ in Equation (7) is the *mean* or the *NBS certified* international joule. Curtis[16] has concluded that the former is larger than the latter by a factor of 1.000026. The difference is small, but is mentioned for the sake of definiteness. We have assumed that the *NBS certified* international joule is intended unless otherwise explicitly stated. The international steam tables kilocalorie has been defined by the factor,

$$860\ kcal/int.kwhr \quad \ldots . (9)$$

with the *mean* international joule intended. This has led to a redefinition of the Btu by the factor,

$$1.8 \text{ Btu kg/kcal lb} \quad \ldots . (10)$$

Accordingly, we compute the factor,

$$0.429989 \text{ Btu g/int. } (NBS \text{ certified}) \text{ joule lb} \quad \ldots . (11)$$

by which we have converted Bureau of Standards calorimetric data to English units for listing in our final tables.

In the $\beta$-experiments were measured values of the quantity,

$$\beta = Tv_t(dp_s/dT) \quad \ldots . (12)$$

The magnitude of $\beta$ in the range 0 to 130 C is so small that the values computed in the manner described above are to be regarded as more accurate than those measured directly. The smallness of $\beta$ also justifies use of the approximate relation, $T = t + 273.16$, between the absolute and the international temperature scales.

The identical relation,

$$s_t = \tau\beta + \int \tau d\alpha \quad \ldots . (13)$$

can be used to calculate values of the specific entropy of the saturated liquid. The required integration is facilitated by making the substitution,

$$1.6986T \times 10^{-(4+0.03755t)} \text{ for } 0.467 \times 10^{-0.036t} \quad \ldots . (14)$$

in the expression for $d\alpha$ derived from the first of Equation (7), the approximation being satisfactory considering the relative smallness of the term in question. Use of the approximate relation, $T = t + 273.16$, is necessary because of lack of information regarding the precise relationship between the two scales.

## Properties of Saturated Solid

The steam table[1] value of the specific volume of the saturated solid (ice) at 32 F is $v_1 = 0.01747$ ft$^3$/lb. This is the same value given in International Critical Tables[17] and is accepted here. Values at lower temperatures have been calculated from data on thermal coefficient of expansion published by Jakob and Erk.[18]

Recently, Osborne[19] has reviewed earlier measurements of the latent heat of fusion and recommended $333.48 \pm 0.2$ *int.joule/g*, or 143.40 Btu per lb, as best value for 32 F. Osborne, Stimson, and Ginnings[9] give for the enthalpy of air-free liquid the value 0.0245 *kcal/kg*, or 0.0441 Btu per lb for atmospheric pressure and 32 F. Accordingly, the enthalpy of ice at atmospheric pressure and 32 F is –143.36 Btu per lb. This can be reduced to saturation pressure by use of the identical relation Equation (3) using the volume data discussed in the preceding paragraph. The final result is $h_1 = -143.40$ Btu per lb at 32 F.

The values of saturation enthalpy $h_1$ at lower temperatures are ob-

ined by integrating the specific eat data of Giauque and Stout[20] om 32 F downward and then ding the value for 32 F given ove. The correction to saturation ressure was found to be entirely gligible.

The value of saturation entropy at 32 F is simply –143.40/491.688 = –0.2916 Btu/lb°$R$. Values at low- temperatures are obtained by in- rating the Giauque and Stout[20] ecific heat data (divided by abso- te temperature) from 32 F down- ard and then adding the above lue for 32 F. Again the correc- on to saturation pressure was und to be entirely negligible.

The Giauque and Stout[20] specific at data are expressed in terms of 15 deg calorie which these authors ve used elsewhere as equal to 1832 international joules (mean) r gram. We have used this value computing the factor for con- rting to English units, namely,

798776 Btu $g$/15 deg cal b.... (15)

## Vapor Enthalpy

Collins and Keyes[6] have per- rmed experiments in which the mperature of steam was restored its initial value, after throttling reduced pressure, by adding a easured quantity of energy elec- ically. In this way they were able measure the enthalpy at various ressures along an isotherm rela- ve to an arbitrary datum. Analy- s by the method of least squares the observed data yielded values the temperature coefficients $B$ in e expression,

$$h = h^\circ - B_{ww}p - \tfrac{1}{2}\,B_{www}p^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

hich were compared with corre- onding values computed from the eyes, Smith, and Gerry[5] (KSG) uation of state. This comparison exhibited in Table 3. It shows at the KSG values for tempera- res below 125 C are not very re- ble. Unfortunately, the observed lues are not sufficiently extensive to yield, of themselves, a reliable formulation covering the whole range of temperature of interest here. They can be used in conjunction with the extremely accurate Bureau of Standards (NBS) calorimetric data, however, to produce a formulation which appears to be sufficiently reliable for present purposes.

In the Bureau of Standards $\gamma$-experiments referred to previously (Properties of Saturated Liquid) the quantity measured is

$$\gamma = Tv_s(dp_s/dT) \quad \ldots\ldots\ldots\ldots \quad (17)$$

The measurements cover the range of 0 to 374 C at very close temperature intervals. The specific enthalpy of the saturated vapor is

$$h_s = \alpha + \gamma \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (18)$$

hence Equation (16) can be written in the form,

$$B_{ww}p_s + \tfrac{1}{2}\,B_{www}p_s^2 = h^\circ - \alpha - \gamma + C \quad \ldots\ldots\ldots \quad (19)$$

the constant $C$ being added to allow for the fact that the values of zero-pressure enthalpy $h^\circ$ calculated from spectroscopic data are purely relative.

$$\left.\begin{aligned} A_{ww} &= -0.0302 + 88.514\tau 10^{233280\tau^3} \quad (\text{ft}^3/\text{lb}) \\ A_{www} &= 67.4\tau^3\, A_{ww}^2 \quad (\text{ft}^3/\text{lb}^2) \\ B_{ww} &= -0.0302 + (0.0302 + A_{ww})\,(2 + 1{,}074{,}300\tau^3) \quad (\text{ft}^3/\text{lb}) \\ B_{www} &= 202.2\tau^3\, A_{ww}^2\, B_{ww} \quad (\text{ft}^3/\text{lb}^2) \end{aligned}\right\} \quad \ldots\ldots (20)$$

To determine $C$, the lefthand member of Equation (19) was evaluated at each of the five temperatures in Table 3, using observed values of $B_{ww}$ and $B_{www}$ (except at 38.94 and 59.44 C, where it was necessary to use KSG equation of state values of $B_{www}$ instead), together with NBS saturation pressures Equation (8). The right-hand member (except for the constant $C$) was evaluated at these same temperatures using our calculated values of zero-pressure enthalpy $h^\circ$ and Bureau of Standards values of $\alpha + \gamma$. The constant $C$ was then adjusted to best satisfy Equation (19), the root mean square deviation being only 0.02 Btu per lb. The term $\frac{1}{2}\,B_{www}p_s^2$ amounts to only 0.07 Btu per lb at 59.44 C and to only 0.02 Btu per lb at 38.94 C; hence the use of KSG values for $B_{www}$ at these temperatures could not have produced significant error in the adjusted value of $C$.

The magnitude of $\frac{1}{2}\,B_{www}p_s^2$ decreases rapidly with decreasing temperature; hence it can be estimated with more than sufficient accuracy in the range 0 to 40 C from the KSG equation of state and the NBS saturation pressures. Values of $B_{ww}p_s$ in the range 0 to 40 C were then calculated from Equation (19) using (*a*) the estimated values of $\frac{1}{2}\,B_{www}p_s^2$; (*b*) our calculated values for zero-pressure enthalpy $h^\circ$; (*c*) weighted-mean values of $\gamma$ given in the Bureau of Standards reports;[9,15] and (*d*), the adjusted value of the constant $C$. Corresponding values of $B_{ww}$ itself were then obtained by dividing the results by the NBS saturation pressures $p_s$. We have formulated our final values of $B_{ww}$ and of $B_{www}$ by means of the empirical Equations (20).

In all of these equations, reciprocal temperature is in °$R^{-1}$. Values of $B_{ww}$ and of $\frac{1}{2}\,B_{www}$ calculated from them are listed in Table 3 for comparison with the observations of Collins and Keyes. The agreement appears to be satisfactory.

In Table 4 are listed the NBS weighted-mean values of the calorimetric quantity $\gamma$. Deviations from these of the NBS smoothed

**Table 3—Enthalpy Coefficients, B**

| t(C) | $B_{ww}$ (int. joule/g atm) | | | $\frac{1}{2}\,B_{www}$ (int. joule/g atm²) | | |
|---|---|---|---|---|---|---|
| | Observed | KSG | Eq. (20) | Observed | KSG | Eq. (20) |
| 38.94 | 28.859 | 33.581 | 29.345 | .... | 10.395 | 13.83 |
| 59.44 | 20.774 | 23.050 | 20.723 | .... | 4.150 | 4.93 |
| 80.02 | 15.195 | 16.616 | 15.304 | 2.283 | 1.910 | 1.99 |
| 100.00 | 11.871 | 12.574 | 11.818 | 0.832 | 0.979 | 0.91 |
| 125.00 | 8.916 | 9.269 | 8.903 | 0.395 | 0.461 | 0.38 |

**Table 4—Values of $\gamma$ (int. joule/g)**

| t(C) | NBS (weighted mean) | NBS (smoothed) | Eq. (19, 20) |
|---|---|---|---|
| 0 | 2500.72 | — 0.54 | — 0.26 |
| 1 | 2497.92 | — 0.08 | 0.16 |
| 5 | 2488.34 | 0.14 | 0.26 |
| 10 | 2476.73 | 0.03 | 0.05 |
| 15 | 2464.81 | 0.21 | 0.19 |
| 20 | 2453.36 | — 0.11 | — 0.14 |
| 25 | 2441.31 | 0.15 | 0.10 |
| 30 | 2429.43 | 0.21 | 0.17 |
| 40 | 2405.87 | 0.01 | 0.01 |
| 50 | 2381.85 | 0.08 | 0.10 |
| 60 | 2357.65 | 0.11 | 0.15 |
| 70 | 2333.40 | — 0.09 | — 0.06 |
| 80 | 2308.51 | 0.02 | 0.04 |
| 90 | 2283.45 | — 0.10 | — 0.10 |
| 100 | 2257.73 | — 0.02 | — 0.03 |
| Root mean square deviation: | | 0.0565 | 0.0452 |

values and of the values calculated from Equations (19 and 20) are shown for the purpose of comparison.

### Vapor Volume

The specific volume of the vapor is to be calculated from the equation,

$$pv = RT + A_{ww}p + A_{www}p^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

which is thermodynamically consistent with Equation (16) through the relation Equation (3) provided that

$$\tau A_{ww} = \int B_{ww}d\tau + C_0$$

$$\tau A_{www} = \int B_{www}d\tau + C_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

To evaluate the constants $C_0$ and $C_1$ requires very accurate determinations of specific volume of at least two different conditions of pressure and temperature. Direct experimental determinations of sufficient accuracy do not seem to be available, at any rate in the range of validity of Equations (20) and (21). However, new and apparently very accurate measurements of saturation pressure in the range 73 to 130 C by Moser and Zmaczynski,[21] together with corresponding values of $\gamma$ can be used in Equation (17) to compute satisfactory values of specific volume at saturation $v_g$. Proceeding in this manner, we have found that the constants $C_0$ and $C_1$ are both zero within the accuracy of the data. Accordingly, these constants have been omitted in writing the first two of Equation (20).

The first of Equations (20) is based on experimental data in the range 0 to 125 C, the second, on data in the range 80 to 125 C. Undoubtedly extrapolation to higher temperatures is unreliable, but it seems safe to extrapolate to lower temperatures along the saturation curve because the terms $A_{ww}p_s$ and $A_{www}p_s^2$ decrease so rapidly with decreasing temperature. As an estimate of the reliability of our formulation it may be stated that our calculated value of the difference between saturation enthalpy $h_g$ and zero-pressure enthalpy $h^0$, at 25 C, is 22.2 int.joul/g, whereas the value recommended by Rossini[22] is 22.0±1.0 int.joule/g.

### Vapor Pressure of Liquid Water

The only published measurements of the vapor pressure of liquid water (saturation pressure, $p_s$) at temperatures below 73 C that have come to our attention are the 1917 PTR (Physikalisch-Technische Reichsanstalt) data. Although these have been formulated differently by different authors,[4,23] they cannot be regarded as being very accurate. Cragoe[24] has kindly shown us his unpublished measurements at 25, 50, 60, and 80 C and these have been compared with our final values in Fig. 1. Because of the smallness of the vapor pressure at low temperatures, it is extremely difficult to measure it accurately there; hence, it seems better to place reliance on values calculated from other data by means of appropriate identical relations of thermodynamics.

Combining (17) and (21) gives the differential equation,

$$\frac{d\ln p_s}{dT} = \frac{\gamma/RT^2}{1 + A_{ww}p_s/RT + A_{www}p_s^2/R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

The negative terms in the denominator are very small compared with unity throughout the range 0 to 100 C; hence, in evaluating them the use of Equation (20) with NBS saturation pressures shown in Equation (8) is justified. The numerator was evaluated from Equations (19 and 20), and the whole righthand member of Equation (23) was reduced to a semi-empirical equation of suitable form for integration. After some rearrangement and reformulation of the smaller terms, a closed expression for the logarithm of the vapor pressure was obtained, namely (Equation 24),

$$\log_{10}p_s = -7.90298\,(T_s/T - 1) + 5.02808\,\log_{10}(T_s/T) - 1.3816\cdot10^{-7}\,[10^{11.344(1-T/T_s)} - 1] + 8.1328\cdot10^{-3}\,[10^{-3.49149(T_s/T-1)} - 1] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

where $p_s$ is in standard atmospheres and $T_s = 373.16\ K = 671.688\ R$.

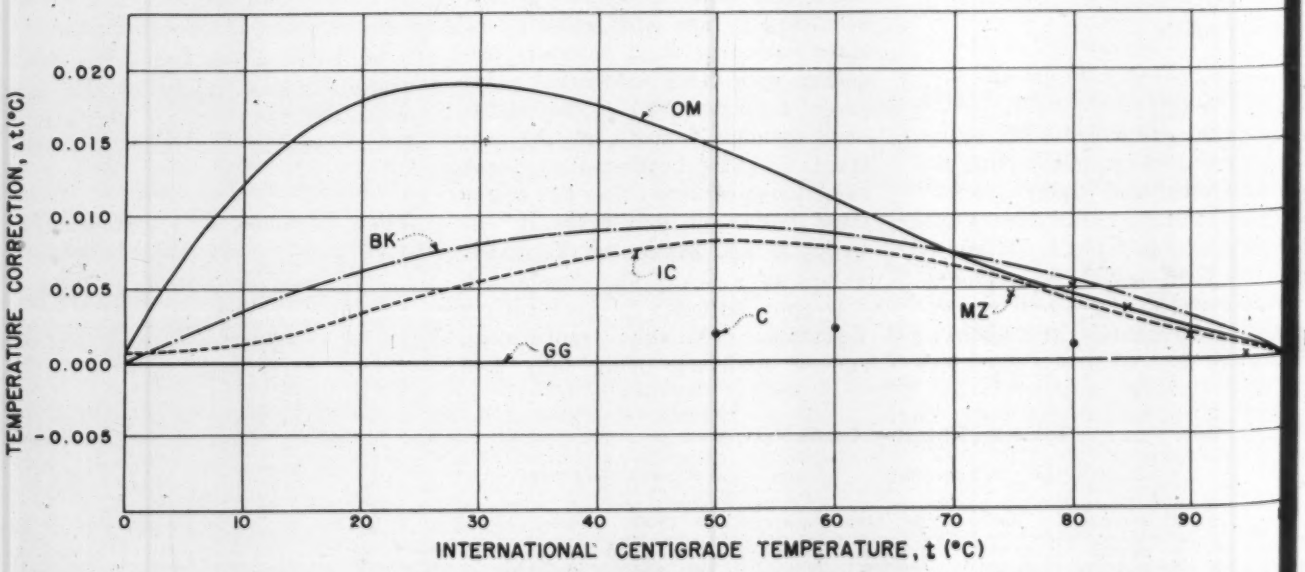


**Fig. 1—Comparison of Vapor Pressure Data**

GG—Goff-Gratch OM—Osborne-Meyers C—Cragoe MZ—Moser-Zmaczynski IC—Third Int. Conf. on Steam Tables
BK—Blaisdell-Kaye

a sample calculation, the four terms on the right of Equation (24) are evaluated below for 0C ($T = 273.16$ K):

$$\log_{10} p_s = -2.893170 + 0.681192 - 0.000151 - 0.007704 = -2.219833;$$

whence $p_s$ (at 32 F) = 0.0060279 atm.

The estimated uncertainty in $\log_{10} p_s$ as given by Equation (24) is 0.02 per cent. In our final tables the values of $p_s$ itself are given in pounds per square inch (lb/in²) for which purpose the conversion factor,

$$14.6959 \text{ lb/in}^2\text{atm} \quad \ldots\ldots\ldots (25)$$

was used.

Fig. 1 shows an interesting comparison of our results (*GG*) with those of Osborne and Meyers[23] (*OM*), with those recommended by the Third International Conference on Steam Tables[4] (*IC*), with those of Moser and Zmaczynski[21] (*MZ*), and with those of Cragoe[24] (*C*). The comparison is made in terms of the correction $\triangle t$ which must be subtracted from the stated temperature $t$ in order to recover the stated vapor pressure $p_s$ on substituting the corrected temperature $t' = t - \triangle t$ into our Equation (24), using the relation $T = t' + 273.16$. The discrepancies between the data of Moser and Zmaczynski and those of Cragoe are especially interesting to note, for they appear to be larger than would be expected considering the degree of precision claimed by these investigators in their measurement of pressure. They can reasonably be attributed, however, to disagreement between the thermometers used, for there is evidence[25] that present specifications of the international centigrade scale are not sufficiently complete or rigid to insure reproducibility to better than ±0.003 C in the range 0 to 100 C.

Blaisdell and Kaye[26] have proposed a centigrade temperature scale $t'$ defined in terms of the resistance $R$ of a suitably constructed platinum thermometer by the cubic,

$$\frac{t'}{100} = \frac{R - R_0}{R_{100} - R_0} + \left(\frac{\delta'}{100}\right)\left(\frac{t'}{100}\right)\left(\frac{t'}{100} - 1\right) + \left(\frac{\gamma'}{t'_s}\right)\left(\frac{t'}{100}\right)\left(\frac{t'}{100} - 1\right)\left(\frac{t'_s}{100} - \frac{t'}{100}\right) \quad \ldots\ldots (26)$$

where $R_0$ and $R_{100}$ denote the measured resistance at the ice point and steam point, respectively. The constant $\delta'$ is to be evaluated by requiring that $t' = t_s' = 444.7$ when $R = R_s$, the measured resistance at the sulphur point. The constant $\gamma'$ is to be determined by requiring that $t' = t'_{Hg} = 356.7$ when $R = R_{Hg}$, the measured resistance at the mercury point. The authors state that the constant $\gamma'$ assumes a value of about —0.035 and that their proposed scale conforms to the absolute scale through the relation, $T = t' + 273.165$, within the experimental error of their measurements. Our Equation (24) expresses the saturation pressure as a function of absolute temperature $T$.

Most laboratory determinations of the saturation pressure are made at temperatures on the international centigrade scale defined by the quadratic,

$$\frac{t}{100} = \frac{R - R_0}{R_{100} - R_0} + \left(\frac{\delta}{100}\right)\left(\frac{t}{100}\right)\left(\frac{t}{100} - 1\right) \quad \ldots\ldots\ldots\ldots (27)$$

where the constant $\delta$ is to be evaluated by requiring that $t = 444.6$ when $R = R_s$. Blaisdell and Kaye[26] state that this quadratic gives $t = 356.57$ for $R = R_{Hg}$ so that addition of 273.165 gives a value for the absolute temperature of the mercury point which is too low by 0.13 C. The difference $\triangle t = t - t'$ between the scale proposed by these investigators and the international centigrade scale can be computed at any temperature $t$ from the data given. According to the findings of Blaisdell and Kaye, the value of saturation pressure $p_s$ calculated from our Equation (24) for $T = t' + 273.16$ should agree with the value measured at temperature $t$ if $t' = t - \triangle t$. Therefore, it is appropriate to plot the computed values of $\triangle t$ on Fig. 1 also. The resulting curve is marked (*BK*).

At first it would appear that Fig. 1 contains evidence supporting the findings of Blaisdell and Kaye regarding the true relation between the international and absolute temperature scales. No definite conclusions can be drawn, however, because the corrections $\triangle t$ appear to be well within the uncertainties of the experimental values.

### Vapor Pressure of Ice

The vapor pressure of ice has been calculated recently by Goff.[27] Harrison[28] has compared his values with the few experimental data available and found good agreement. In preceding paragraphs some of the data on which Goff based his calculations have been revised so that it appears desirable, in the interest of consistency, to revise the calculations also.

The differential equation to be used is the same as Equation (23) except that the enthalpy of sublimation $h_{1g}$ replaces $\gamma$ in the numerator on the right. Strictly speaking, the quantity $p_s v_1/RT$ should be subtracted from the denominator, but its magnitude is so very small compared with unity that no appreciable error is committed in neglecting to do so. From Equation (16),

$$h_{1g} = h^\circ - h_1 - B_{\ast\ast} p_s - \tfrac{1}{2} B_{\ast\ast\ast} p_s^2$$

The difference, $h^\circ - h_1$, between zero-pressure enthalpy of the vapor and saturation enthalpy of the solid is a large quantity which varies only slightly with temperature. Its value at 0C (32 F) is 1218.74 Btu per

**Table 5—Recalculated Values of the Vapor Pressure of Ice**

| $t$(F) | $\log_{10}(p_s/p_0)$ | $t$(F) | $\log_{10}(p_s/p_0)$ | $t$(F) | $\log_{10}(p_s/p_0)$ |
|---|---|---|---|---|---|
| 32 | 0.00000 | — 80 | $\bar{3}.11588$ | — 192 | $\bar{9}.84521$ |
| 16 | $\bar{1}.67130$ | — 96 | $\bar{4}.55943$ | — 208 | $\bar{10}.71610$ |
| 0 | $\bar{1}.31957$ | — 112 | $\bar{5}.95227$ | — 224 | $\bar{11}.43649$ |
| — 16 | $\bar{2}.94235$ | — 128 | $\bar{5}.28723$ | — 240 | $\bar{13}.97398$ |
| — 32 | $\bar{2}.53686$ | — 144 | $\bar{6}.55570$ | — 256 | $\bar{14}.28606$ |
| — 48 | $\bar{2}.09987$ | — 160 | $\bar{7}.74721$ | — 272 | $\bar{16}.31581$ |
| — 64 | $\bar{3}.62766$ | — 176 | $\bar{8}.84898$ | — 288 | $\bar{19}.98529$ |

## Table 6 —Thermodynamic Properties of Water at Saturation: Solid-Vapor

| Temp. Fahr. t | Abs. Pressure $p_s$ Lb/Sq In | Abs. Pressure $p_s$ In Hg | Specific Volume, cu ft/lb Sat.Solid $v_i$ | Specific Volume, cu ft/lb Evap. $v_{ig} \times 10^{-3}$ | Specific Volume, cu ft/lb Sat.Vapor $v_g \times 10^{-3}$ | Enthalpy, Btu/lb Sat.Solid $h_i$ | Enthalpy, Btu/lb Evap. $h_{ig}$ | Enthalpy, Btu/lb Sat.Vapor $h_g$ | Entropy, Btu/lb°F Sat.Solid $s_i$ | Entropy, Btu/lb°F Evap. $s_{ig}$ | Entropy, Btu/lb°F Sat.Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0.08856 | 0.1803 | 0.01747 | 3.306 | 3.306 | -143.40 | 1218.56 | 1075.16 | -0.2916 | 2.4783 | 2.1867 | 32 |
| 31 | 0.08461 | 0.1723 | 0.01747 | 3.455 | 3.455 | -143.90 | 1218.63 | 1074.73 | -0.2927 | 2.4836 | 2.1908 | 31 |
| 30 | 0.08080 | 0.1645 | 0.01747 | 3.606 | 3.606 | -144.40 | 1218.69 | 1074.29 | -0.2937 | 2.4887 | 2.1950 | 30 |
| 29 | 0.07715 | 0.1571 | 0.01747 | 3.771 | 3.771 | -144.90 | 1218.75 | 1073.85 | -0.2947 | 2.4936 | 2.1988 | 29 |
| 28 | 0.07365 | 0.1500 | 0.01746 | 3.943 | 3.943 | -145.40 | 1218.81 | 1073.41 | -0.2957 | 2.4991 | 2.2034 | 28 |
| 27 | 0.07030 | 0.1431 | 0.01746 | 4.122 | 4.122 | -145.90 | 1218.87 | 1072.97 | -0.2968 | 2.5045 | 2.2077 | 27 |
| 26 | 0.06708 | 0.1366 | 0.01746 | 4.311 | 4.311 | -146.40 | 1218.93 | 1072.53 | -0.2978 | 2.5097 | 2.2119 | 26 |
| 25 | 0.06400 | 0.1303 | 0.01746 | 4.509 | 4.509 | -146.89 | 1218.98 | 1072.09 | -0.2988 | 2.5150 | 2.2162 | 25 |
| 24 | 0.06106 | 0.1243 | 0.01746 | 4.717 | 4.717 | -147.39 | 1219.03 | 1071.64 | -0.2998 | 2.5203 | 2.2205 | 24 |
| 23 | 0.05823 | 0.1186 | 0.01746 | 4.936 | 4.936 | -147.88 | 1219.10 | 1071.22 | -0.3008 | 2.5256 | 2.2248 | 23 |
| 22 | 0.05552 | 0.1130 | 0.01746 | 5.166 | 5.166 | -148.38 | 1219.16 | 1070.78 | -0.3019 | 2.5310 | 2.2291 | 22 |
| 21 | 0.05293 | 0.1078 | 0.01745 | 5.406 | 5.406 | -148.87 | 1219.21 | 1070.34 | -0.3029 | 2.5364 | 2.2335 | 21 |
| 20 | 0.05045 | 0.1027 | 0.01745 | 5.662 | 5.662 | -149.36 | 1219.26 | 1069.90 | -0.3039 | 2.5417 | 2.2378 | 20 |
| 19 | 0.04808 | 0.09790 | 0.01745 | 5.929 | 5.929 | -149.85 | 1219.31 | 1069.46 | -0.3049 | 2.5471 | 2.2422 | 19 |
| 18 | 0.04581 | 0.09326 | 0.01745 | 6.210 | 6.210 | -150.34 | 1219.36 | 1069.02 | -0.3060 | 2.5526 | 2.2466 | 18 |
| 17 | 0.04363 | 0.08884 | 0.01745 | 6.505 | 6.505 | -150.83 | 1219.41 | 1068.58 | -0.3070 | 2.5581 | 2.2511 | 17 |
| 16 | 0.04156 | 0.08461 | 0.01745 | 6.817 | 6.817 | -151.32 | 1219.46 | 1068.14 | -0.3080 | 2.5636 | 2.2556 | 16 |
| 15 | 0.03957 | 0.08056 | 0.01744 | 7.144 | 7.144 | -151.80 | 1219.50 | 1067.70 | -0.3090 | 2.5690 | 2.2600 | 15 |
| 14 | 0.03767 | 0.07669 | 0.01744 | 7.489 | 7.489 | -152.29 | 1219.55 | 1067.26 | -0.3101 | 2.5746 | 2.2645 | 14 |
| 13 | 0.03585 | 0.07300 | 0.01744 | 7.851 | 7.851 | -152.77 | 1219.59 | 1066.82 | -0.3111 | 2.5801 | 2.2690 | 13 |
| 12 | 0.03412 | 0.06946 | 0.01744 | 8.234 | 8.234 | -153.26 | 1219.64 | 1066.38 | -0.3121 | 2.5857 | 2.2736 | 12 |
| 11 | 0.03246 | 0.06608 | 0.01744 | 8.636 | 8.636 | -153.74 | 1219.68 | 1065.94 | -0.3131 | 2.5912 | 2.2781 | 11 |
| 10 | 0.03087 | 0.06286 | 0.01744 | 9.060 | 9.060 | -154.22 | 1219.72 | 1065.50 | -0.3142 | 2.5969 | 2.2827 | 10 |
| 9 | 0.02936 | 0.05977 | 0.01744 | 9.507 | 9.507 | -154.70 | 1219.76 | 1065.06 | -0.3152 | 2.6025 | 2.2873 | 9 |
| 8 | 0.02791 | 0.05683 | 0.01743 | 9.979 | 9.979 | -155.18 | 1219.80 | 1064.62 | -0.3162 | 2.6081 | 2.2919 | 8 |
| 7 | 0.02653 | 0.05402 | 0.01743 | 10.48 | 10.48 | -155.66 | 1219.84 | 1064.18 | -0.3172 | 2.6138 | 2.2966 | 7 |
| 6 | 0.02521 | 0.05134 | 0.01743 | 11.00 | 11.00 | -156.14 | 1219.88 | 1063.74 | -0.3182 | 2.6194 | 2.3012 | 6 |

| Temp. Fahr. t | Abs. Pressure $p_s \times 10^3$ Lb/Sq In | Abs. Pressure $p_s \times 10^3$ In Hg | Specific Volume, cu ft/lb Sat.Solid $v_i$ | Specific Volume, cu ft/lb Evap. $v_{ig} \times 10^{-5}$ | Specific Volume, cu ft/lb Sat.Vapor $v_g \times 10^{-5}$ | Enthalpy, Btu/lb Sat.Solid $h_i$ | Enthalpy, Btu/lb Evap. $h_{ig}$ | Enthalpy, Btu/lb Sat.Vapor $h_g$ | Entropy, Btu/lb°F Sat.Solid $s_i$ | Entropy, Btu/lb°F Evap. $s_{ig}$ | Entropy, Btu/lb°F Sat.Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -25 | 4.687 | 9.420 | 0.01739 | 0.5596 | 0.5596 | -170.46 | 1220.51 | 1050.06 | -0.3501 | 2.8078 | 2.4577 | -25 |
| -26 | 4.563 | 8.868 | 0.01738 | 0.5921 | 0.5921 | -170.91 | 1220.51 | 1049.60 | -0.3511 | 2.8143 | 2.4632 | -26 |
| -27 | 4.113 | 8.373 | 0.01738 | 0.6267 | 0.6267 | -171.35 | 1220.51 | 1049.16 | -0.3521 | 2.8207 | 2.4686 | -27 |
| -28 | 3.876 | 7.891 | 0.01738 | 0.6634 | 0.6634 | -171.80 | 1220.52 | 1048.72 | -0.3532 | 2.8274 | 2.4742 | -28 |
| -29 | 3.658 | 7.435 | 0.01738 | 0.7025 | 0.7025 | -172.24 | 1220.52 | 1048.28 | -0.3542 | 2.8339 | 2.4797 | -29 |
| -30 | 3.440 | 7.003 | 0.01738 | 0.7441 | 0.7441 | -172.68 | 1220.52 | 1047.84 | -0.3552 | 2.8405 | 2.4853 | -30 |
| -31 | 3.239 | 6.595 | 0.01738 | 0.7883 | 0.7883 | -173.13 | 1220.53 | 1047.40 | -0.3562 | 2.8470 | 2.4908 | -31 |
| -32 | 3.049 | 6.206 | 0.01738 | 0.8356 | 0.8356 | -173.57 | 1220.52 | 1046.96 | -0.3573 | 2.8538 | 2.4965 | -32 |
| -33 | 2.870 | 5.843 | 0.01738 | 0.8857 | 0.8857 | -174.01 | 1220.52 | 1046.51 | -0.3583 | 2.8604 | 2.5021 | -33 |
| -34 | 2.700 | 5.497 | 0.01737 | 0.9391 | 0.9391 | -174.45 | 1220.52 | 1046.07 | -0.3593 | 2.8671 | 2.5078 | -34 |
| -35 | 2.540 | 5.170 | 0.01737 | 0.9961 | 0.9961 | -174.88 | 1220.51 | 1045.63 | -0.3604 | 2.8739 | 2.5135 | -35 |
| -36 | 2.388 | 4.862 | 0.01737 | 1.057 | 1.057 | -175.32 | 1220.51 | 1045.19 | -0.3614 | 2.8807 | 2.5193 | -36 |
| -37 | 2.245 | 4.570 | 0.01737 | 1.122 | 1.122 | -175.76 | 1220.50 | 1044.74 | -0.3624 | 2.8874 | 2.5250 | -37 |
| -38 | 2.110 | 4.295 | 0.01737 | 1.191 | 1.191 | -176.19 | 1220.49 | 1044.30 | -0.3634 | 2.8942 | 2.5308 | -38 |
| -39 | 1.982 | 4.035 | 0.01737 | 1.264 | 1.264 | -176.63 | 1220.49 | 1043.86 | -0.3645 | 2.9012 | 2.5367 | -39 |
| -40 | 1.861 | 3.790 | 0.01737 | 1.343 | 1.343 | -177.06 | 1220.48 | 1043.42 | -0.3655 | 2.9080 | 2.5425 | -40 |
| -41 | 1.748 | 3.559 | 0.01736 | 1.427 | 1.427 | -177.49 | 1220.47 | 1042.98 | -0.3665 | 2.9149 | 2.5484 | -41 |
| -42 | 1.641 | 3.340 | 0.01736 | 1.516 | 1.516 | -177.92 | 1220.45 | 1042.53 | -0.3676 | 2.9219 | 2.5543 | -42 |
| -43 | 1.539 | 3.134 | 0.01736 | 1.612 | 1.612 | -178.35 | 1220.44 | 1042.09 | -0.3686 | 2.9289 | 2.5603 | -43 |
| -44 | 1.444 | 2.940 | 0.01736 | 1.715 | 1.715 | -178.78 | 1220.43 | 1041.65 | -0.3696 | 2.9359 | 2.5663 | -44 |
| -45 | 1.354 | 2.757 | 0.01736 | 1.824 | 1.824 | -179.21 | 1220.42 | 1041.21 | -0.3707 | 2.9430 | 2.5723 | -45 |
| -46 | 1.270 | 2.585 | 0.01736 | 1.941 | 1.941 | -179.64 | 1220.40 | 1040.76 | -0.3717 | 2.9501 | 2.5784 | -46 |
| -47 | 1.190 | 2.422 | 0.01736 | 2.066 | 2.066 | -180.06 | 1220.38 | 1040.32 | -0.3727 | 2.9571 | 2.5844 | -47 |
| -48 | 1.115 | 2.270 | 0.01736 | 2.200 | 2.200 | -180.49 | 1220.37 | 1039.88 | -0.3738 | 2.9643 | 2.5905 | -48 |
| -49 | 1.044 | 2.126 | 0.01735 | 2.343 | 2.343 | -180.92 | 1220.36 | 1039.44 | -0.3748 | 2.9715 | 2.5967 | -49 |
| -50 | 0.9776 | 1.990 | 0.01735 | 2.496 | 2.496 | -181.34 | 1220.34 | 1039.00 | -0.3758 | 2.9786 | 2.6028 | -50 |
| -51 | 0.9151 | 1.863 | 0.01735 | 2.660 | 2.660 | -181.76 | 1220.31 | 1038.56 | -0.3769 | 2.9860 | 2.6091 | -51 |
| -52 | 0.8568 | 1.743 | 0.01735 | 2.836 | 2.836 | -182.18 | 1220.29 | 1038.11 | -0.3779 | 2.9932 | 2.6153 | -52 |
| -53 | 0.8009 | 1.631 | 0.01736 | 3.024 | 3.024 | -182.60 | 1220.27 | 1037.67 | -0.3789 | 3.0006 | 2.6216 | -53 |
| -54 | 0.7489 | 1.525 | 0.01735 | 3.226 | 3.226 | -183.02 | 1220.25 | 1037.23 | -0.3800 | 3.0079 | 2.6279 | -54 |

| Temp. Fahr. t | Abs. Pressure $p_s \times 10^2$ Lb/Sq In | Abs. Pressure $p_s \times 10^2$ In Hg | Specific Volume, cu ft/lb Sat.Solid $v_i$ | Specific Volume, cu ft/lb Evap. $v_{ig} \times 10^{-4}$ | Specific Volume, cu ft/lb Sat.Vapor $v_g \times 10^{-4}$ | Enthalpy, Btu/lb Sat.Solid $h_i$ | Enthalpy, Btu/lb Evap. $h_{ig}$ | Enthalpy, Btu/lb Sat.Vapor $h_g$ | Entropy, Btu/lb°F Sat.Solid $s_i$ | Entropy, Btu/lb°F Evap. $s_{ig}$ | Entropy, Btu/lb°F Sat.Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 2.396 | 4.878 | 0.01743 | 1.155 | 1.155 | -156.61 | 1219.90 | 1063.29 | -0.3193 | 2.6252 | 2.3059 | 5 |
| 4 | 2.276 | 4.633 | 0.01743 | 1.214 | 1.214 | -157.09 | 1219.94 | 1062.85 | -0.3203 | 2.6309 | 2.3106 | 4 |
| 3 | 2.161 | 4.400 | 0.01743 | 1.275 | 1.275 | -157.56 | 1219.97 | 1062.41 | -0.3213 | 2.6367 | 2.3154 | 3 |
| 2 | 2.052 | 4.178 | 0.01742 | 1.340 | 1.340 | -158.04 | 1220.01 | 1061.97 | -0.3224 | 2.6425 | 2.3201 | 2 |
| 1 | 1.948 | 3.966 | 0.01742 | 1.408 | 1.408 | -158.51 | 1220.04 | 1061.53 | -0.3234 | 2.6483 | 2.3249 | 1 |
| 0 | 1.849 | 3.764 | 0.01742 | 1.481 | 1.481 | -158.98 | 1220.07 | 1061.09 | -0.3244 | 2.6541 | 2.3297 | 0 |
| -1 | 1.754 | 3.572 | 0.01742 | 1.557 | 1.557 | -159.45 | 1220.10 | 1060.65 | -0.3254 | 2.6600 | 2.3346 | -1 |
| -2 | 1.664 | 3.388 | 0.01742 | 1.638 | 1.638 | -159.92 | 1220.13 | 1060.21 | -0.3264 | 2.6658 | 2.3394 | -2 |
| -3 | 1.578 | 3.213 | 0.01742 | 1.723 | 1.723 | -160.39 | 1220.15 | 1059.76 | -0.3275 | 2.6718 | 2.3443 | -3 |
| -4 | 1.496 | 3.047 | 0.01742 | 1.814 | 1.814 | -160.86 | 1220.18 | 1059.32 | -0.3285 | 2.6777 | 2.3492 | -4 |
| -5 | 1.419 | 2.889 | 0.01741 | 1.909 | 1.909 | -161.33 | 1220.21 | 1058.88 | -0.3295 | 2.6836 | 2.3541 | -5 |
| -6 | 1.344 | 2.737 | 0.01741 | 2.010 | 2.010 | -161.79 | 1220.23 | 1058.44 | -0.3306 | 2.6896 | 2.3590 | -6 |
| -7 | 1.274 | 2.594 | 0.01741 | 2.116 | 2.116 | -162.26 | 1220.26 | 1058.00 | -0.3316 | 2.6956 | 2.3640 | -7 |
| -8 | 1.207 | 2.457 | 0.01741 | 2.229 | 2.229 | -162.72 | 1220.28 | 1057.56 | -0.3326 | 2.7016 | 2.3690 | -8 |
| -9 | 1.143 | 2.327 | 0.01741 | 2.349 | 2.349 | -163.18 | 1220.30 | 1057.12 | -0.3336 | 2.7076 | 2.3740 | -9 |
| -10 | 1.082 | 2.203 | 0.01741 | 2.475 | 2.475 | -163.65 | 1220.32 | 1056.67 | -0.3347 | 2.7136 | 2.3791 | -10 |
| -11 | 1.024 | 2.086 | 0.01740 | 2.609 | 2.609 | -164.11 | 1220.34 | 1056.23 | -0.3357 | 2.7198 | 2.3841 | -11 |
| -12 | 0.9694 | 1.974 | 0.01740 | 2.750 | 2.750 | -164.57 | 1220.36 | 1055.79 | -0.3367 | 2.7259 | 2.3892 | -12 |
| -13 | 0.9172 | 1.867 | 0.01740 | 2.901 | 2.901 | -165.03 | 1220.38 | 1055.35 | -0.3377 | 2.7320 | 2.3943 | -13 |
| -14 | 0.8676 | 1.766 | 0.01740 | 3.060 | 3.060 | -165.48 | 1220.39 | 1054.91 | -0.3388 | 2.7383 | 2.3996 | -14 |
| -15 | 0.8204 | 1.670 | 0.01740 | 3.228 | 3.228 | -165.94 | 1220.41 | 1054.47 | -0.3398 | 2.7444 | 2.4046 | -15 |
| -16 | 0.7757 | 1.579 | 0.01740 | 3.407 | 3.407 | -166.40 | 1220.42 | 1054.02 | -0.3408 | 2.7506 | 2.4098 | -16 |
| -17 | 0.7332 | 1.493 | 0.01740 | 3.596 | 3.596 | -166.86 | 1220.43 | 1053.58 | -0.3418 | 2.7568 | 2.4150 | -17 |
| -18 | 0.6928 | 1.410 | 0.01740 | 3.797 | 3.797 | -167.31 | 1220.45 | 1053.14 | -0.3429 | 2.7632 | 2.4203 | -18 |
| -19 | 0.6545 | 1.333 | 0.01739 | 4.011 | 4.011 | -167.76 | 1220.46 | 1052.70 | -0.3439 | 2.7695 | 2.4256 | -19 |
| -20 | 0.6181 | 1.259 | 0.01739 | 4.237 | 4.237 | -168.21 | 1220.47 | 1052.26 | -0.3449 | 2.7757 | 2.4308 | -20 |
| -21 | 0.5836 | 1.188 | 0.01739 | 4.477 | 4.477 | -168.66 | 1220.48 | 1051.82 | -0.3460 | 2.7822 | 2.4362 | -21 |
| -22 | 0.5509 | 1.122 | 0.01739 | 4.732 | 4.732 | -169.12 | 1220.49 | 1051.37 | -0.3470 | 2.7885 | 2.4415 | -22 |
| -23 | 0.5199 | 1.059 | 0.01739 | 5.003 | 5.003 | -169.56 | 1220.49 | 1050.93 | -0.3480 | 2.7949 | 2.4469 | -23 |
| -24 | 0.4905 | 0.9987 | 0.01739 | 5.290 | 5.290 | -170.01 | 1220.50 | 1050.49 | -0.3490 | 2.8013 | 2.4523 | -24 |

| Temp. Fahr. t | Abs. Pressure $p_s \times 10^4$ Lb/Sq In | Abs. Pressure $p_s \times 10^4$ In Hg | Specific Volume, cu ft/lb Sat.Solid $v_i$ | Specific Volume, cu ft/lb Evap. $v_{ig} \times 10^{-5}$ | Specific Volume, cu ft/lb Sat.Vapor $v_g \times 10^{-5}$ | Enthalpy, Btu/lb Sat.Solid $-h_i$ | Enthalpy, Btu/lb Evap. $h_{ig}$ | Enthalpy, Btu/lb Sat.Vapor $h_g$ | Entropy, Btu/lb°F Sat.Solid $s_i$ | Entropy, Btu/lb°F Evap. $s_{ig}$ | Entropy, Btu/lb°F Sat.Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -55 | 7.001 | 14.26 | 0.01734 | 3.443 | 3.443 | -183.44 | 1220.83 | 1036.79 | -0.3810 | 3.0152 | 2.6342 | -55 |
| -56 | 6.543 | 13.32 | 0.01734 | 3.675 | 3.675 | -183.86 | 1220.80 | 1036.34 | -0.3820 | 3.0226 | 2.6406 | -56 |
| -57 | 6.112 | 12.44 | 0.01734 | 3.925 | 3.925 | -184.28 | 1220.18 | 1035.90 | -0.3831 | 3.0301 | 2.6470 | -57 |
| -58 | 5.708 | 11.62 | 0.01734 | 4.192 | 4.192 | -184.69 | 1220.15 | 1035.46 | -0.3841 | 3.0376 | 2.6536 | -58 |
| -59 | 5.328 | 10.85 | 0.01734 | 4.479 | 4.479 | -185.11 | 1220.13 | 1035.02 | -0.3851 | 3.0450 | 2.6599 | -59 |
| -60 | 4.972 | 10.12 | 0.01734 | 4.788 | 4.788 | -185.52 | 1220.10 | 1034.58 | -0.3862 | 3.0526 | 2.6664 | -60 |
| -61 | 4.639 | 9.444 | 0.01734 | 5.120 | 5.120 | -185.93 | 1220.06 | 1034.13 | -0.3872 | 3.0602 | 2.6730 | -61 |
| -62 | 4.326 | 8.808 | 0.01734 | 5.476 | 5.476 | -186.35 | 1220.04 | 1033.69 | -0.3882 | 3.0678 | 2.6796 | -62 |
| -63 | 4.033 | 8.211 | 0.01733 | 5.859 | 5.859 | -186.76 | 1220.01 | 1033.25 | -0.3893 | 3.0755 | 2.6862 | -63 |
| -64 | 3.758 | 7.652 | 0.01733 | 6.272 | 6.272 | -187.17 | 1219.98 | 1032.81 | -0.3903 | 3.0832 | 2.6929 | -64 |
| -65 | 3.501 | 7.128 | 0.01733 | 6.715 | 6.715 | -187.58 | 1219.94 | 1032.36 | -0.3914 | 3.0910 | 2.6996 | -65 |
| -66 | 3.260 | 6.638 | 0.01733 | 7.193 | 7.193 | -187.98 | 1219.90 | 1031.92 | -0.3924 | 3.0987 | 2.7063 | -66 |
| -67 | 3.035 | 6.180 | 0.01733 | 7.707 | 7.707 | -188.39 | 1219.87 | 1031.48 | -0.3934 | 3.1064 | 2.7130 | -67 |
| -68 | 2.824 | 5.751 | 0.01733 | 8.261 | 8.261 | -188.80 | 1219.84 | 1031.04 | -0.3945 | 3.1143 | 2.7198 | -68 |
| -69 | 2.627 | 5.349 | 0.01732 | 8.856 | 8.856 | -189.20 | 1219.80 | 1030.60 | -0.3955 | 3.1222 | 2.7267 | -69 |
| -70 | 2.443 | 4.974 | 0.01732 | 9.501 | 9.501 | -189.61 | 1219.76 | 1030.15 | -0.3965 | 3.1301 | 2.7336 | -70 |
| -71 | 2.271 | 4.624 | 0.01732 | 10.20 | 10.20 | -190.01 | 1219.72 | 1029.71 | -0.3976 | 3.1381 | 2.7405 | -71 |
| -72 | 2.110 | 4.296 | 0.01732 | 10.94 | 10.94 | -190.41 | 1219.68 | 1029.27 | -0.3986 | 3.1460 | 2.7474 | -72 |
| -73 | 1.960 | 3.991 | 0.01732 | 11.75 | 11.75 | -190.82 | 1219.65 | 1028.83 | -0.3996 | 3.1540 | 2.7544 | -73 |
| -74 | 1.820 | 3.705 | 0.01732 | 12.62 | 12.62 | -191.22 | 1219.60 | 1028.38 | -0.4007 | 3.1622 | 2.7615 | -74 |
| -75 | 1.689 | 3.439 | 0.01732 | 13.56 | 13.56 | -191.62 | 1219.56 | 1027.94 | -0.4017 | 3.1702 | 2.7685 | -75 |
| -76 | 1.567 | 3.191 | 0.01732 | 14.58 | 14.58 | -192.01 | 1219.51 | 1027.50 | -0.4028 | 3.1784 | 2.7756 | -76 |
| -77 | 1.453 | 2.959 | 0.01732 | 15.68 | 15.68 | -192.41 | 1219.47 | 1027.06 | -0.4038 | 3.1866 | 2.7828 | -77 |
| -78 | 1.347 | 2.743 | 0.01731 | 16.87 | 16.87 | -192.81 | 1219.43 | 1026.62 | -0.4048 | 3.1948 | 2.7900 | -78 |
| -79 | 1.249 | 2.542 | 0.01731 | 18.16 | 18.16 | -193.20 | 1219.37 | 1026.17 | -0.4058 | 3.2030 | 2.7972 | -79 |
| -80 | 1.157 | 2.355 | 0.01731 | 19.55 | 19.55 | -193.60 | 1219.33 | 1025.73 | -0.4069 | 3.2114 | 2.8045 | -80 |
| -81 | 1.071 | 2.181 | 0.01731 | 21.06 | 21.06 | -193.99 | 1219.28 | 1025.29 | -0.4079 | 3.2197 | 2.8118 | -81 |
| -82 | 0.9913 | 2.018 | 0.01731 | 22.70 | 22.70 | -194.38 | 1219.23 | 1024.85 | -0.4090 | 3.2282 | 2.8192 | -82 |
| -83 | 0.9171 | 1.867 | 0.01731 | 24.46 | 24.46 | -194.78 | 1219.18 | 1024.40 | -0.4100 | 3.2366 | 2.8266 | -83 |
| -84 | 0.8482 | 1.727 | 0.01731 | 26.36 | 26.36 | -195.16 | 1219.12 | 1023.96 | -0.4110 | 3.2450 | 2.8340 | -84 |

lb, according to the present analysis; hence, we may write

$$h^\circ - h_1 = 1218.74 + \triangle h$$

where $\triangle h$ is a small quantity which is readily evaluated from data discussed in preceding paragraphs. Letting $p_0$ denote the value of the vapor pressure at 0C, we obtain,

$$\log_{10}(p_s/p_0) = -9.76670(T_0/T - 1) + 0.43429\int_{T_0}^{T} \frac{\triangle h/RT - B_{ww}p_s/RT - \frac{1}{2}B_{www}p_s^2/RT}{1 - A_{ww}p_s/RT - A_{www}p_s^2/RT}\,dT/T + 0.43429\int_{T_0}^{T} \frac{(1218.74/RT)(A_{ww}p_s/RT + A_{www}p_s^2/RT)}{1 - A_{ww}p_s/RT - A_{www}p_s^2/RT}\,dT/T \quad \ldots\ldots (28)$$

where $T_0 = 273.16\ K = 491.688\ R$.

The results of the above recalculation agree with those previously published well within their estimated uncertainty, namely, $\pm 0.03$ per cent in $\log_{10}(p_s/p_0)$. The recalculations are summarized in Table 5.

To obtain the vapor pressure $p_s$ itself from the data summarized in Table 5 requires to know its value at 0C, namely $p_0$. According to International Critical Tables,[29] the triple point of water is at 32.0176 F. At this point the vapor pressure of the solid is identical with that of the liquid. At 32 F the difference between them has been estimated[2] as 0.0000006 atm. But from Equation (24) the vapor pressure of the liquid at 32 F is 0.0060279 atm; accordingly, that of the solid at 32 F is

$$p_0 = 0.0060273 \text{ atm.} \quad \ldots\ldots (29)$$

### Vapor Entropy

From Equation (21) can be derived an expression for reduced entropy, namely,

$$s + R\ln p = s^\circ + C_{ww}p + \tfrac{1}{2}C_{www}p^2 \quad \ldots\ldots (30)$$

*where*

$$C_{ww} = \tau A_{ww} - \tau B_{ww}$$
$$C_{www} = \tau A_{www} - \tau B_{www} \quad \ldots\ldots (31)$$

Table 6 —Thermodynamic Properties of Water at Saturation: Solid-Vapor (*Concluded*)

| Temp. Fahr. t | Abs. Pressure $p_s \times 10^6$ Lb/Sq In | Abs. Pressure $p_s \times 10^6$ In Hg | Specific Volume, cu ft/lb Sat. Solid $v_1$ | Specific Volume, cu ft/lb Evap. $v_{1g} \times 10^{-6}$ | Specific Volume, cu ft/lb Sat. Vapor $v_g \times 10^{-6}$ | Enthalpy, Btu/lb Sat. Solid $h_1$ | Enthalpy, Btu/lb Evap. $h_{1g}$ | Enthalpy, Btu/lb Sat. Vapor $h_g$ | Entropy, Btu/lb°F Sat. Solid $s_1$ | Entropy, Btu/lb°F Evap. $s_{1g}$ | Entropy, Btu/lb°F Sat. Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -85 | 7.841 | 15.96 | 0.01750 | 2.846 | 2.846 | -195.56 | 1219.09 | 1023.53 | -0.4121 | 2.8236 | 2.8115 | -85 |
| -86 | 7.845 | 14.75 | 0.01750 | 3.072 | 3.072 | -196.94 | 1219.04 | 1022.10 | -0.4151 | 2.8481 | 2.8330 | -86 |
| -87 | 6.668 | 13.63 | 0.01750 | 3.317 | 3.317 | -198.33 | 1218.97 | 1020.64 | -0.4182 | 2.8729 | 2.8547 | -87 |
| -88 | 6.179 | 12.58 | 0.01750 | 3.585 | 3.585 | -199.72 | 1218.88 | 1019.16 | -0.4213 | 2.8980 | 2.8767 | -88 |
| -89 | 5.708 | 11.61 | 0.01750 | 3.872 | 3.872 | -197.10 | 1218.88 | 1021.78 | -0.4158 | 2.8660 | 2.8502 | -89 |
| -90 | 5.260 | 10.71 | 0.01750 | 4.186 | 4.186 | -197.49 | 1218.80 | 1021.31 | -0.4173 | 2.8769 | 2.8595 | -90 |
| -91 | 4.850 | 9.876 | 0.01750 | 4.528 | 4.528 | -197.87 | 1218.74 | 1020.87 | -0.4189 | 2.8873 | 2.8684 | -91 |
| -92 | 4.470 | 9.108 | 0.01750 | 4.899 | 4.899 | -198.25 | 1218.68 | 1020.43 | -0.4204 | 2.8981 | 2.8777 | -92 |
| -93 | 4.119 | 8.388 | 0.01750 | 5.303 | 5.303 | -198.64 | 1218.62 | 1019.98 | -0.4804 | 2.9089 | 2.8869 | -93 |
| -94 | 3.793 | 7.728 | 0.01750 | 5.743 | 5.743 | -199.02 | 1218.56 | 1019.54 | -0.4814 | 2.9198 | 2.8964 | -94 |
| -95 | 3.491 | 7.109 | 0.01750 | 6.223 | 6.223 | -199.40 | 1218.50 | 1019.10 | -0.4825 | 2.9187 | 2.9062 | -95 |
| -96 | 3.218 | 6.559 | 0.01750 | 6.745 | 6.745 | -199.78 | 1218.44 | 1018.66 | -0.4835 | 2.9308 | 2.9157 | -96 |
| -97 | 2.964 | 6.014 | 0.01750 | 7.314 | 7.314 | -800.15 | 1218.37 | 1018.22 | -0.4846 | 2.9363 | 2.9247 | -97 |
| -98 | 2.725 | 5.526 | 0.01750 | 7.936 | 7.936 | -800.53 | 1218.30 | 1017.77 | -0.4856 | 2.9464 | 2.9340 | -98 |
| -99 | 2.494 | 5.079 | 0.01750 | 8.613 | 8.613 | -800.90 | 1218.23 | 1017.33 | -0.4866 | 2.9570 | 2.9435 | -99 |
| -100 | 2.291 | 4.654 | 0.01750 | 9.352 | 9.352 | -801.28 | 1218.17 | 1016.89 | -0.4877 | 2.9668 | 2.9531 | -100 |
| -101 | 2.103 | 4.281 | 0.01750 | 10.16 | 10.16 | -801.65 | 1218.10 | 1016.46 | -0.4887 | 2.9760 | 2.9673 | -101 |
| -102 | 1.929 | 3.928 | 0.01750 | 11.04 | 11.04 | -802.03 | 1218.04 | 1016.01 | -0.4898 | 2.9863 | 2.9765 | -102 |
| -103 | 1.769 | 3.601 | 0.01750 | 12.01 | 12.01 | -802.40 | 1217.96 | 1015.56 | -0.4908 | 2.9956 | 2.9858 | -103 |
| -104 | 1.622 | 3.301 | 0.01750 | 13.07 | 13.07 | -802.77 | 1217.90 | 1015.12 | -0.4918 | 2.9982 | 2.9964 | -104 |
| -105 | 1.486 | 3.025 | 0.01750 | 14.22 | 14.22 | -803.14 | 1217.82 | 1014.68 | -0.4389 | 3.0035 | 3.0006 | -105 |
| -106 | 1.360 | 2.770 | 0.01750 | 15.49 | 15.49 | -803.51 | 1217.75 | 1014.24 | -0.4559 | 3.0130 | 3.0091 | -106 |
| -107 | 1.245 | 2.536 | 0.01750 | 16.87 | 16.87 | -803.88 | 1217.68 | 1013.80 | -0.4350 | 3.0226 | 3.0176 | -107 |
| -108 | 1.139 | 2.319 | 0.01750 | 18.39 | 18.39 | -804.24 | 1217.60 | 1013.36 | -0.4360 | 3.0321 | 3.0261 | -108 |
| -109 | 1.041 | 2.120 | 0.01750 | 20.04 | 20.04 | -804.61 | 1217.53 | 1012.91 | -0.4370 | 3.0418 | 3.0348 | -109 |
| -110 | 0.9517 | 1.938 | 0.01750 | 21.89 | 21.89 | -804.98 | 1217.45 | 1012.47 | -0.4381 | 3.0515 | 3.0434 | -110 |
| -111 | 0.8693 | 1.770 | 0.01727 | 23.89 | 23.89 | -805.34 | 1217.37 | 1018.03 | -0.4391 | 3.0613 | 3.0521 | -111 |
| -112 | 0.7936 | 1.616 | 0.01727 | 26.10 | 26.10 | -805.70 | 1217.29 | 1011.59 | -0.4402 | 3.0711 | 3.0609 | -112 |
| -113 | 0.7241 | 1.474 | 0.01727 | 28.52 | 28.52 | -806.07 | 1217.21 | 1011.14 | -0.4413 | 3.0809 | 3.0697 | -113 |
| -114 | 0.6604 | 1.344 | 0.01727 | 31.18 | 31.18 | -806.43 | 1217.13 | 1010.70 | -0.4423 | 3.0909 | 3.0796 | -114 |

| Temp. Fahr. t | Abs. Pressure $p_s \times 10^6$ Lb/Sq In | Abs. Pressure $p_s \times 10^6$ In Hg | Specific Volume, cu ft/lb Sat. Solid $v_1$ | Specific Volume, cu ft/lb Evap. $v_{1g} \times 10^{-6}$ | Specific Volume, cu ft/lb Sat. Vapor $v_g \times 10^{-9}$ | Enthalpy, Btu/lb Sat. Solid $h_1$ | Enthalpy, Btu/lb Evap. $h_{1g}$ | Enthalpy, Btu/lb Sat. Vapor $h_g$ | Entropy, Btu/lb°F Sat. Solid $s_1$ | Entropy, Btu/lb°F Evap. $s_{1g}$ | Entropy, Btu/lb°F Sat. Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -115 | 6.019 | 12.26 | 0.01727 | 3.411 | 3.411 | -809.79 | 1217.06 | 1010.85 | -0.4483 | 3.0308 | 3.0075 | -115 |
| -116 | 5.494 | 11.16 | 0.01727 | 3.753 | 3.753 | -807.16 | 1216.97 | 1009.82 | -0.4444 | 3.0409 | 3.0065 | -116 |
| -117 | 4.993 | 10.17 | 0.01727 | 4.088 | 4.088 | -807.51 | 1216.89 | 1009.38 | -0.4454 | 3.0511 | 3.1056 | -117 |
| -118 | 4.544 | 9.251 | 0.01727 | 4.480 | 4.480 | -807.86 | 1216.80 | 1008.94 | -0.4464 | 3.0611 | 3.1147 | -118 |
| -119 | 4.133 | 9.414 | 0.01726 | 4.911 | 4.911 | -809.22 | 1216.71 | 1008.49 | -0.4476 | 3.0713 | 3.1239 | -119 |
| -120 | 3.757 | 7.649 | 0.01726 | 5.386 | 5.386 | -808.58 | 1216.65 | 1008.06 | -0.4480 | 3.0812 | 3.1330 | -120 |
| -121 | 3.413 | 6.949 | 0.01726 | 5.911 | 5.911 | -809.93 | 1216.54 | 1007.61 | -0.4496 | 3.0919 | 3.1423 | -121 |
| -122 | 3.099 | 6.310 | 0.01726 | 6.491 | 6.491 | -809.28 | 1216.45 | 1007.17 | -0.4506 | 3.1016 | 3.1510 | -122 |
| -123 | 2.812 | 5.726 | 0.01726 | 7.131 | 7.131 | -809.64 | 1216.37 | 1006.73 | -0.4517 | 3.1110 | 3.1610 | -123 |
| -124 | 2.551 | 5.194 | 0.01726 | 7.830 | 7.830 | -809.99 | 1216.27 | 1006.28 | -0.4527 | 3.1208 | 3.1706 | -124 |
| -125 | 8.312 | 4.709 | 0.01726 | 8.628 | 8.628 | -810.34 | 1216.18 | 1005.84 | -0.4538 | 3.1300 | 3.1800 | -125 |
| -126 | 2.096 | 4.266 | 0.01726 | 9.459 | 9.459 | -810.69 | 1216.09 | 1005.40 | -0.4549 | 3.1396 | 3.1896 | -126 |
| -127 | 1.897 | 3.862 | 0.01726 | 10.45 | 10.45 | -811.04 | 1216.00 | 1004.96 | -0.4559 | 3.1492 | 3.1992 | -127 |
| -128 | 1.716 | 3.494 | 0.01726 | 11.51 | 11.51 | -811.39 | 1215.91 | 1004.52 | -0.4569 | 3.1589 | 3.2089 | -128 |
| -129 | 1.553 | 3.160 | 0.01725 | 12.69 | 12.69 | -811.73 | 1215.80 | 1004.07 | -0.4580 | 3.1685 | 3.2186 | -129 |
| -130 | 1.403 | 2.856 | 0.01725 | 14.00 | 14.00 | -812.08 | 1215.71 | 1003.63 | -0.4590 | 3.1784 | 3.2284 | -130 |
| -131 | 1.267 | 2.579 | 0.01725 | 15.45 | 15.45 | -812.43 | 1215.62 | 1003.19 | -0.4601 | 3.1880 | 3.2383 | -131 |
| -132 | 1.144 | 2.329 | 0.01725 | 17.07 | 17.07 | -812.77 | 1215.53 | 1002.75 | -0.4611 | 3.1976 | 3.2488 | -132 |
| -133 | 1.032 | 2.101 | 0.01725 | 18.86 | 18.86 | -813.11 | 1215.43 | 1002.31 | -0.4622 | 3.2075 | 3.2583 | -133 |
| -134 | 0.9301 | 1.894 | 0.01725 | 20.86 | 20.86 | -813.46 | 1215.32 | 1001.86 | -0.4632 | 3.7315 | 3.2683 | -134 |
| -135 | 0.8380 | 1.706 | 0.01725 | 23.09 | 23.09 | -813.80 | 1215.22 | 1001.42 | -0.4643 | 3.7440 | 3.2798 | -135 |
| -136 | 0.7546 | 1.536 | 0.01725 | 25.55 | 25.55 | -814.14 | 1215.12 | 1000.98 | -0.4653 | 3.7540 | 3.2887 | -136 |
| -137 | 0.6790 | 1.382 | 0.01724 | 28.21 | 28.21 | -814.48 | 1215.02 | 1000.54 | -0.4664 | 3.7643 | 3.2979 | -137 |
| -138 | 0.6106 | 1.243 | 0.01724 | 31.38 | 31.38 | -814.82 | 1214.92 | 1000.10 | -0.4674 | 3.7746 | 3.3072 | -138 |
| -139 | 0.5487 | 1.117 | 0.01724 | 34.81 | 34.81 | -815.16 | 1214.82 | 999.66 | -0.4686 | 3.7861 | 3.3175 | -139 |
| -140 | 0.4928 | 1.003 | 0.01724 | 38.64 | 38.64 | -815.49 | 1214.70 | 999.21 | -0.4695 | 3.7956 | 3.3261 | -140 |
| -141 | 0.4423 | 0.9006 | 0.01724 | 42.92 | 42.92 | -815.83 | 1214.60 | 998.77 | -0.4706 | 3.8058 | 3.3352 | -141 |
| -142 | 0.3967 | 0.8078 | 0.01724 | 47.70 | 47.70 | -816.16 | 1214.49 | 998.33 | -0.4716 | 3.8159 | 3.3443 | -142 |
| -143 | 0.3556 | 0.7240 | 0.01724 | 53.05 | 53.05 | -816.50 | 1214.39 | 997.89 | -0.4727 | 3.8259 | 3.3532 | -143 |
| -144 | 0.3184 | 0.6483 | 0.01724 | 59.05 | 59.05 | -816.83 | 1214.28 | 997.45 | -0.4737 | 3.8364 | 3.3627 | -144 |

## Table 7—Thermodynamic Properties of Water at Saturation: Liquid-Vapor

| Temp. Fahr. t | Abs. Pressure $p_s$ Lb/Sq In | Abs. Pressure $p_s$ In Hg | Specific Volume, cu ft/lb Sat. Liquid $v_f$ | Specific Volume, cu ft/lb Evap. $v_{fg}$ | Specific Volume, cu ft/lb Sat. Vapor $v_g$ | Enthalpy, Btu/lb Sat. Liquid $h_f$ | Enthalpy, Btu/lb Evap. $h_{fg}$ | Enthalpy, Btu/lb Sat. Vapor $h_g$ | Entropy, Btu/lb°F Sat. Liquid $s_f$ | Entropy, Btu/lb°F Evap. $s_{fg}$ | Entropy, Btu/lb°F Sat. Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 0.088586 | 0.18036 | 0.01602 | 3304.6 | 3304.6 | 0.00 | 1075.16 | 1075.16 | 0.00000 | 2.1867 | 2.1867 | 32 |
| 33 | 0.092227 | 0.18778 | 0.01602 | 3180.5 | 3180.5 | 1.01 | 1074.59 | 1075.60 | 0.00205 | 2.1811 | 2.1831 | 33 |
| 34 | 0.095999 | 0.19546 | 0.01602 | 3061.7 | 3061.7 | 2.01 | 1074.03 | 1076.04 | 0.00409 | 2.1755 | 2.1796 | 34 |
| 35 | 0.099908 | 0.20342 | 0.01602 | 2947.8 | 2947.8 | 3.02 | 1073.46 | 1076.48 | 0.00612 | 2.1700 | 2.1761 | 35 |
| 36 | 0.10396 | 0.21166 | 0.01602 | 2838.7 | 2838.7 | 4.02 | 1072.90 | 1076.92 | 0.00815 | 2.1644 | 2.1726 | 36 |
| 37 | 0.10815 | 0.22020 | 0.01602 | 2734.1 | 2734.1 | 5.03 | 1072.33 | 1077.36 | 0.01018 | 2.1589 | 2.1691 | 37 |
| 38 | 0.11249 | 0.22904 | 0.01602 | 2633.8 | 2633.8 | 6.03 | 1071.77 | 1077.80 | 0.01220 | 2.1535 | 2.1657 | 38 |
| 39 | 0.11699 | 0.23819 | 0.01602 | 2537.6 | 2537.6 | 7.04 | 1071.20 | 1078.24 | 0.01422 | 2.1480 | 2.1622 | 39 |
| 40 | 0.12164 | 0.24767 | 0.01602 | 2445.4 | 2445.4 | 8.04 | 1070.64 | 1078.68 | 0.01623 | 2.1426 | 2.1588 | 40 |
| 41 | 0.12646 | 0.25748 | 0.01602 | 2356.9 | 2356.9 | 9.05 | 1070.06 | 1079.11 | 0.01824 | 2.1372 | 2.1554 | 41 |
| 42 | 0.13145 | 0.26763 | 0.01602 | 2272.0 | 2272.0 | 10.05 | 1069.50 | 1079.55 | 0.02024 | 2.1318 | 2.1520 | 42 |
| 43 | 0.13660 | 0.27813 | 0.01602 | 2190.5 | 2190.5 | 11.05 | 1068.94 | 1079.99 | 0.02224 | 2.1265 | 2.1487 | 43 |
| 44 | 0.14194 | 0.28899 | 0.01602 | 2112.3 | 2112.3 | 12.06 | 1068.37 | 1080.43 | 0.02423 | 2.1211 | 2.1453 | 44 |
| 45 | 0.14746 | 0.30023 | 0.01602 | 2037.3 | 2037.3 | 13.06 | 1067.81 | 1080.87 | 0.02622 | 2.1158 | 2.1420 | 45 |
| 46 | 0.15317 | 0.31185 | 0.01602 | 1965.2 | 1965.2 | 14.06 | 1067.24 | 1081.30 | 0.02820 | 2.1105 | 2.1387 | 46 |
| 47 | 0.15907 | 0.32387 | 0.01602 | 1896.0 | 1896.0 | 15.06 | 1066.68 | 1081.74 | 0.03018 | 2.1052 | 2.1354 | 47 |
| 48 | 0.16517 | 0.33629 | 0.01602 | 1829.5 | 1829.5 | 16.07 | 1066.11 | 1082.18 | 0.03216 | 2.0999 | 2.1321 | 48 |
| 49 | 0.17148 | 0.34913 | 0.01602 | 1765.7 | 1765.7 | 17.07 | 1065.55 | 1082.62 | 0.03413 | 2.0947 | 2.1288 | 49 |
| 50 | 0.17799 | 0.36240 | 0.01602 | 1704.3 | 1704.3 | 18.07 | 1064.99 | 1083.06 | 0.03610 | 2.0895 | 2.1256 | 50 |
| 51 | 0.18473 | 0.37611 | 0.01602 | 1645.4 | 1645.4 | 19.07 | 1064.42 | 1083.49 | 0.03806 | 2.0843 | 2.1223 | 51 |
| 52 | 0.19169 | 0.39028 | 0.01602 | 1588.7 | 1588.7 | 20.07 | 1063.86 | 1083.93 | 0.04002 | 2.0791 | 2.1191 | 52 |
| 53 | 0.19888 | 0.40492 | 0.01603 | 1534.3 | 1534.3 | 21.07 | 1063.30 | 1084.37 | 0.04197 | 2.0739 | 2.1159 | 53 |
| 54 | 0.20630 | 0.42003 | 0.01603 | 1481.9 | 1481.9 | 22.08 | 1062.72 | 1084.80 | 0.04392 | 2.0688 | 2.1127 | 54 |
| 55 | 0.21397 | 0.43564 | 0.01603 | 1431.5 | 1431.5 | 23.08 | 1062.16 | 1085.24 | 0.04587 | 2.0637 | 2.1096 | 55 |
| 56 | 0.22188 | 0.45176 | 0.01603 | 1383.1 | 1383.1 | 24.08 | 1061.60 | 1085.68 | 0.04781 | 2.0586 | 2.1064 | 56 |
| 57 | 0.23006 | 0.46840 | 0.01603 | 1336.5 | 1336.5 | 25.08 | 1061.04 | 1086.12 | 0.04975 | 2.0535 | 2.1033 | 57 |
| 58 | 0.23849 | 0.48556 | 0.01603 | 1291.7 | 1291.7 | 26.08 | 1060.47 | 1086.55 | 0.05168 | 2.0486 | 2.1002 | 58 |
| 59 | 0.24720 | 0.50330 | 0.01603 | 1248.6 | 1248.6 | 27.08 | 1059.91 | 1086.99 | 0.05361 | 2.0434 | 2.0970 | 59 |
| 60 | 0.25618 | 0.52160 | 0.01603 | 1207.1 | 1207.1 | 28.08 | 1059.34 | 1087.42 | 0.05553 | 2.0385 | 2.0940 | 60 |
| 61 | 0.26545 | 0.54047 | 0.01604 | 1167.2 | 1167.2 | 29.08 | 1058.78 | 1087.86 | 0.05746 | 2.0334 | 2.0909 | 61 |
| 62 | 0.27502 | 0.55994 | 0.01604 | 1128.7 | 1128.7 | 30.08 | 1058.22 | 1088.30 | 0.05937 | 2.0284 | 2.0878 | 62 |
| 63 | 0.28488 | 0.58002 | 0.01604 | 1091.7 | 1091.7 | 31.08 | 1057.65 | 1088.73 | 0.06129 | 2.0235 | 2.0848 | 63 |
| 64 | 0.29505 | 0.60073 | 0.01604 | 1056.1 | 1056.1 | 32.08 | 1057.09 | 1089.17 | 0.06320 | 2.0186 | 2.0818 | 64 |
| 65 | 0.30554 | 0.62209 | 0.01604 | 1021.7 | 1021.7 | 33.08 | 1056.52 | 1089.60 | 0.06510 | 2.0136 | 2.0787 | 65 |
| 66 | 0.31636 | 0.64411 | 0.01604 | 988.63 | 988.65 | 34.07 | 1055.97 | 1090.04 | 0.06700 | 2.0087 | 2.0757 | 66 |
| 67 | 0.32750 | 0.66681 | 0.01605 | 956.76 | 956.78 | 35.07 | 1055.40 | 1090.47 | 0.06890 | 2.0039 | 2.0728 | 67 |
| 68 | 0.33900 | 0.69021 | 0.01605 | 926.06 | 926.08 | 36.07 | 1054.84 | 1090.91 | 0.07080 | 1.9990 | 2.0698 | 68 |
| 69 | 0.35084 | 0.71432 | 0.01605 | 896.47 | 896.49 | 37.07 | 1054.27 | 1091.34 | 0.07269 | 1.9941 | 2.0668 | 69 |
| 70 | 0.36304 | 0.73916 | 0.01605 | 867.95 | 867.97 | 38.07 | 1053.71 | 1091.78 | 0.07458 | 1.9893 | 2.0639 | 70 |
| 71 | 0.37561 | 0.76476 | 0.01605 | 840.45 | 840.47 | 39.07 | 1053.14 | 1092.21 | 0.07646 | 1.9845 | 2.0610 | 71 |
| 72 | 0.38856 | 0.79113 | 0.01606 | 813.96 | 813.97 | 40.07 | 1052.58 | 1092.65 | 0.07834 | 1.9797 | 2.0580 | 72 |
| 73 | 0.40190 | 0.81829 | 0.01606 | 788.38 | 788.40 | 41.07 | 1052.01 | 1093.08 | 0.08022 | 1.9749 | 2.0551 | 73 |
| 74 | 0.41564 | 0.84626 | 0.01606 | 763.73 | 763.75 | 42.06 | 1051.46 | 1093.52 | 0.08209 | 1.9701 | 2.0522 | 74 |
| 75 | 0.42979 | 0.87506 | 0.01606 | 739.95 | 739.97 | 43.06 | 1050.89 | 1093.95 | 0.08396 | 1.9654 | 2.0494 | 75 |
| 76 | 0.44435 | 0.90472 | 0.01606 | 717.01 | 717.03 | 44.06 | 1050.32 | 1094.38 | 0.08582 | 1.9607 | 2.0465 | 76 |
| 77 | 0.45935 | 0.93524 | 0.01607 | 694.88 | 694.90 | 45.06 | 1049.76 | 1094.82 | 0.08769 | 1.9560 | 2.0437 | 77 |
| 78 | 0.47479 | 0.96666 | 0.01607 | 673.52 | 673.54 | 46.06 | 1049.19 | 1095.25 | 0.08954 | 1.9513 | 2.0408 | 78 |
| 79 | 0.49066 | 0.99900 | 0.01607 | 652.91 | 652.93 | 47.06 | 1048.62 | 1095.68 | 0.09140 | 1.9466 | 2.0380 | 79 |
| 80 | 0.50701 | 1.0323 | 0.01607 | 633.01 | 633.03 | 48.06 | 1048.07 | 1096.12 | 0.09325 | 1.9419 | 2.0352 | 80 |
| 81 | 0.52382 | 1.0665 | 0.01608 | 613.80 | 613.82 | 49.06 | 1047.50 | 1096.55 | 0.09510 | 1.9373 | 2.0324 | 81 |
| 82 | 0.54112 | 1.1017 | 0.01608 | 595.25 | 595.27 | 50.06 | 1046.93 | 1096.98 | 0.09694 | 1.9326 | 2.0297 | 82 |
| 83 | 0.55892 | 1.1380 | 0.01608 | 577.34 | 577.36 | 51.06 | 1046.37 | 1097.42 | 0.09878 | 1.9281 | 2.0269 | 83 |
| 84 | 0.57722 | 1.1752 | 0.01608 | 560.04 | 560.06 | 52.05 | 1045.80 | 1097.85 | 0.10062 | 1.9236 | 2.0242 | 84 |
| 85 | 0.59604 | 1.2136 | 0.01609 | 543.33 | 543.35 | 53.05 | 1045.23 | 1098.28 | 0.10246 | 1.9189 | 2.0214 | 85 |
| 86 | 0.61540 | 1.2530 | 0.01609 | 527.19 | 527.21 | 54.04 | 1044.67 | 1098.71 | 0.10429 | 1.9144 | 2.0187 | 86 |
| 87 | 0.63530 | 1.2935 | 0.01609 | 511.60 | 511.62 | 55.04 | 1044.10 | 1099.14 | 0.10611 | 1.9099 | 2.0160 | 87 |
| 88 | 0.65575 | 1.3351 | 0.01610 | 496.52 | 496.54 | 56.04 | 1043.54 | 1099.58 | 0.10794 | 1.9054 | 2.0133 | 88 |
| 89 | 0.67678 | 1.3779 | 0.01610 | 481.96 | 481.98 | 57.04 | 1042.97 | 1100.01 | 0.10976 | 1.9008 | 2.0106 | 89 |
| 90 | 0.69838 | 1.4219 | 0.01610 | 467.88 | 467.90 | 58.04 | 1042.40 | 1100.44 | 0.11158 | 1.8963 | 2.0079 | 90 |
| 91 | 0.72059 | 1.4671 | 0.01610 | 454.26 | 454.28 | 59.03 | 1041.84 | 1100.87 | 0.11339 | 1.8919 | 2.0053 | 91 |
| 92 | 0.74340 | 1.5136 | 0.01611 | 441.10 | 441.12 | 60.03 | 1041.27 | 1101.30 | 0.11520 | 1.8874 | 2.0026 | 92 |
| 93 | 0.76684 | 1.5613 | 0.01611 | 428.38 | 428.40 | 61.03 | 1040.70 | 1101.73 | 0.11701 | 1.8830 | 2.0000 | 93 |
| 94 | 0.79091 | 1.6103 | 0.01611 | 416.09 | 416.09 | 62.03 | 1040.13 | 1102.16 | 0.11881 | 1.8786 | 1.9974 | 94 |
| 95 | 0.81564 | 1.6607 | 0.01612 | 404.17 | 404.19 | 63.03 | 1039.56 | 1102.59 | 0.12061 | 1.8741 | 1.9947 | 95 |
| 96 | 0.84103 | 1.7124 | 0.01612 | 392.65 | 392.67 | 64.02 | 1039.00 | 1103.02 | 0.12241 | 1.8698 | 1.9922 | 96 |
| 97 | 0.86711 | 1.7655 | 0.01612 | 381.51 | 381.53 | 65.02 | 1038.43 | 1103.45 | 0.12420 | 1.8654 | 1.9896 | 97 |
| 98 | 0.89388 | 1.8200 | 0.01612 | 370.73 | 370.75 | 66.02 | 1037.86 | 1103.88 | 0.12600 | 1.8610 | 1.9870 | 98 |
| 99 | 0.92137 | 1.8759 | 0.01613 | 360.30 | 360.32 | 67.02 | 1037.29 | 1104.31 | 0.12778 | 1.8566 | 1.9844 | 99 |
| 100 | 0.94959 | 1.9334 | 0.01613 | 350.20 | 350.22 | 68.02 | 1036.72 | 1104.74 | 0.12957 | 1.8523 | 1.9819 | 100 |
| 101 | 0.97854 | 1.9923 | 0.01614 | 340.42 | 340.44 | 69.01 | 1036.16 | 1105.17 | 0.13135 | 1.8480 | 1.9793 | 101 |
| 102 | 1.0083 | 2.0529 | 0.01614 | 330.96 | 330.98 | 70.01 | 1035.58 | 1105.59 | 0.13313 | 1.8437 | 1.9768 | 102 |
| 103 | 1.0388 | 2.1149 | 0.01614 | 321.80 | 321.82 | 71.01 | 1035.01 | 1106.02 | 0.13490 | 1.8394 | 1.9743 | 103 |
| 104 | 1.0700 | 2.1786 | 0.01614 | 312.93 | 312.95 | 72.01 | 1034.44 | 1106.45 | 0.13667 | 1.8351 | 1.9718 | 104 |
| 105 | 1.1021 | 2.2440 | 0.01615 | 304.34 | 304.36 | 73.01 | 1033.87 | 1106.88 | 0.13844 | 1.8309 | 1.9693 | 105 |
| 106 | 1.1351 | 2.3110 | 0.01615 | 296.02 | 296.04 | 74.01 | 1033.29 | 1107.30 | 0.14021 | 1.8266 | 1.9668 | 106 |
| 107 | 1.1688 | 2.3798 | 0.01616 | 287.96 | 287.98 | 75.00 | 1032.73 | 1107.73 | 0.14197 | 1.8224 | 1.9644 | 107 |
| 108 | 1.2035 | 2.4503 | 0.01616 | 280.14 | 280.16 | 76.00 | 1032.16 | 1108.16 | 0.14373 | 1.8182 | 1.9619 | 108 |
| 109 | 1.2390 | 2.5226 | 0.01616 | 272.58 | 272.60 | 77.00 | 1031.58 | 1108.58 | 0.14549 | 1.8140 | 1.9595 | 109 |
| 110 | 1.2754 | 2.5968 | 0.01617 | 265.24 | 265.26 | 78.00 | 1031.01 | 1109.01 | 0.14724 | 1.8098 | 1.9570 | 110 |
| 111 | 1.3128 | 2.6728 | 0.01617 | 258.14 | 258.16 | 79.00 | 1030.44 | 1109.44 | 0.14899 | 1.8056 | 1.9546 | 111 |
| 112 | 1.3510 | 2.7507 | 0.01617 | 251.25 | 251.27 | 80.00 | 1029.86 | 1109.86 | 0.15074 | 1.8015 | 1.9522 | 112 |
| 113 | 1.3902 | 2.8306 | 0.01618 | 244.57 | 244.59 | 80.99 | 1029.30 | 1110.29 | 0.15248 | 1.7973 | 1.9498 | 113 |
| 114 | 1.4305 | 2.9125 | 0.01618 | 238.10 | 238.12 | 81.99 | 1028.72 | 1110.71 | 0.15423 | 1.7932 | 1.9474 | 114 |
| 115 | 1.4717 | 2.9963 | 0.01618 | 231.82 | 231.84 | 82.99 | 1028.15 | 1111.14 | 0.15596 | 1.7890 | 1.9450 | 115 |
| 116 | 1.5139 | 3.0823 | 0.01619 | 225.73 | 225.75 | 83.99 | 1027.57 | 1111.56 | 0.15770 | 1.7849 | 1.9426 | 116 |
| 117 | 1.5571 | 3.1703 | 0.01619 | 219.83 | 219.85 | 84.99 | 1026.99 | 1111.98 | 0.15943 | 1.7809 | 1.9403 | 117 |
| 118 | 1.6014 | 3.2606 | 0.01620 | 214.10 | 214.12 | 85.99 | 1026.42 | 1112.41 | 0.16116 | 1.7767 | 1.9379 | 118 |
| 119 | 1.6468 | 3.3530 | 0.01620 | 208.54 | 208.56 | 86.98 | 1025.85 | 1112.83 | 0.16289 | 1.7727 | 1.9356 | 119 |
| 120 | 1.6933 | 3.4477 | 0.01620 | 203.16 | 203.18 | 87.98 | 1025.28 | 1113.26 | 0.16461 | 1.7687 | 1.9333 | 120 |
| 121 | 1.7409 | 3.5446 | 0.01621 | 197.93 | 197.95 | 88.98 | 1024.70 | 1113.68 | 0.16634 | 1.7647 | 1.9310 | 121 |
| 122 | 1.7897 | 3.6439 | 0.01621 | 192.85 | 192.87 | 89.98 | 1024.12 | 1114.10 | 0.16805 | 1.7606 | 1.9286 | 122 |
| 123 | 1.8396 | 3.7455 | 0.01622 | 187.93 | 187.95 | 90.98 | 1023.54 | 1114.52 | 0.16977 | 1.7566 | 1.9264 | 123 |
| 124 | 1.8907 | 3.8496 | 0.01622 | 183.15 | 183.17 | 91.98 | 1022.96 | 1114.94 | 0.17148 | 1.7526 | 1.9241 | 124 |
| 125 | 1.9430 | 3.9561 | 0.01622 | 178.51 | 178.53 | 92.98 | 1022.39 | 1115.37 | 0.17319 | 1.7486 | 1.9218 | 125 |
| 126 | 1.9966 | 4.0651 | 0.01623 | 174.00 | 174.02 | 93.98 | 1021.81 | 1115.79 | 0.17490 | 1.7446 | 1.9196 | 126 |
| 127 | 2.0514 | 4.1768 | 0.01623 | 169.63 | 169.65 | 94.97 | 1021.24 | 1116.21 | 0.17660 | 1.7407 | 1.9173 | 127 |
| 128 | 2.1075 | 4.2910 | 0.01624 | 165.38 | 165.40 | 95.97 | 1020.66 | 1116.63 | 0.17830 | 1.7367 | 1.9150 | 128 |
| 129 | 2.1649 | 4.4078 | 0.01624 | 161.26 | 161.28 | 96.97 | 1020.08 | 1117.05 | 0.18000 | 1.7328 | 1.9128 | 129 |

## Table 7—Thermodynamic Properties of Water at Saturation: Liquid-Vapor *(Continued)*

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Table 7—Thermodynamic Properties of Water at Saturation: Liquid-Vapor

Table 7—Thermodynamic Properties of Water at Saturation: Liquid-Vapor (*Concluded*)

| Temp. Fahr. t | Abs. Pressure $p_s$ Lb/Sq In | Abs. Pressure $p_s$ In Hg | Specific Volume, cu ft/lb Sat.Liquid $v_f$ | Specific Volume, cu ft/lb Evap. $v_{fg}$ | Specific Volume, cu ft/lb Sat.Vapor $v_g$ | Enthalpy, Btu/lb Sat.Liquid $h_f$ | Enthalpy, Btu/lb Evap. $h_{fg}$ | Enthalpy, Btu/lb Sat.Vapor $h_g$ | Entropy, Btu/lb°F Sat.Liquid $s_f$ | Entropy, Btu/lb°F Evap. $s_{fg}$ | Entropy, Btu/lb°F Sat.Vapor $s_g$ | Temp. Fahr. t |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 130 | 2.2257 | 4.5874 | 0.01625 | 157.25 | 157.27 | 97.97 | 1019.50 | 1117.47 | 0.18170 | 1.7839 | 1.9106 | 130 |
| 131 | 2.2539 | 4.6498 | 0.01625 | 153.36 | 153.38 | 98.97 | 1018.92 | 1117.89 | 0.18359 | 1.7850 | 1.9094 | 131 |
| 132 | 2.2825 | 4.7150 | 0.01626 | 149.58 | 149.60 | 99.97 | 1018.34 | 1118.31 | 0.18606 | 1.7861 | 1.9062 | 132 |
| 133 | 2.4081 | 4.9830 | 0.01626 | 145.91 | 145.93 | 100.97 | 1017.76 | 1118.73 | 0.18676 | 1.7872 | 1.9240 | 133 |
| 134 | 2.4725 | 5.0560 | 0.01626 | 142.34 | 142.36 | 101.97 | 1017.18 | 1119.16 | 0.18845 | 1.7884 | 1.9018 | 134 |
| 135 | 2.5382 | 5.1579 | 0.01627 | 138.87 | 138.89 | 102.97 | 1016.59 | 1119.56 | 0.19013 | 1.7895 | 1.8996 | 135 |
| 136 | 2.6055 | 5.3049 | 0.01627 | 135.50 | 135.52 | 103.97 | 1016.01 | 1119.98 | 0.19181 | 1.7906 | 1.8974 | 136 |
| 137 | 2.6743 | 5.4550 | 0.01628 | 132.22 | 132.24 | 104.97 | 1015.43 | 1120.40 | 0.19348 | 1.7918 | 1.8953 | 137 |
| 138 | 2.7446 | 5.5981 | 0.01628 | 129.04 | 129.06 | 105.97 | 1014.85 | 1120.82 | 0.19516 | 1.7929 | 1.8931 | 138 |
| 139 | 2.8165 | 5.7345 | 0.01629 | 125.94 | 125.96 | 106.97 | 1014.26 | 1121.23 | 0.19683 | 1.7940 | 1.8910 | 139 |
| 140 | 2.8900 | 5.8948 | 0.01629 | 122.94 | 122.96 | 107.96 | 1013.69 | 1121.65 | 0.19850 | 1.7951 | 1.8889 | 140 |
| 141 | 2.9651 | 6.0371 | 0.01630 | 120.03 | 120.05 | 108.96 | 1013.11 | 1122.07 | 0.20016 | 1.7962 | 1.8867 | 141 |
| 142 | 3.0419 | 6.1934 | 0.01630 | 117.18 | 117.20 | 109.96 | 1012.53 | 1122.49 | 0.20182 | 1.7973 | 1.8846 | 142 |
| 143 | 3.1204 | 6.3538 | 0.01631 | 114.40 | 114.42 | 110.96 | 1011.94 | 1122.90 | 0.20348 | 1.7983 | 1.8825 | 143 |
| 144 | 3.2006 | 6.5184 | 0.01631 | 111.70 | 111.72 | 111.96 | 1011.36 | 1123.31 | 0.20514 | 1.7993 | 1.8804 | 144 |
| 145 | 3.2825 | 6.6872 | 0.01632 | 109.09 | 109.11 | 112.96 | 1010.77 | 1123.73 | 0.20679 | 1.8004 | 1.8783 | 145 |
| 146 | 3.3662 | 6.8596 | 0.01632 | 106.54 | 106.56 | 113.96 | 1010.19 | 1124.14 | 0.20845 | 1.8015 | 1.8762 | 146 |
| 147 | 3.4517 | 7.0377 | 0.01633 | 104.06 | 104.08 | 114.96 | 1009.59 | 1124.55 | 0.21010 | 1.8025 | 1.8741 | 147 |
| 148 | 3.5390 | 7.2056 | 0.01633 | 101.65 | 101.67 | 115.96 | 1009.01 | 1124.97 | 0.21174 | 1.8035 | 1.8721 | 148 |
| 149 | 3.6282 | 7.3978 | 0.01634 | 99.306 | 99.322 | 116.96 | 1008.42 | 1125.38 | 0.21339 | 1.8046 | 1.8701 | 149 |
| 150 | 3.7194 | 7.5782 | 0.01634 | 97.028 | 97.044 | 117.96 | 1007.83 | 1125.79 | 0.21503 | 1.8056 | 1.8680 | 150 |
| 151 | 3.8124 | 7.7688 | 0.01635 | 94.799 | 94.815 | 118.96 | 1007.24 | 1126.20 | 0.21667 | 1.8066 | 1.8660 | 151 |
| 152 | 3.9074 | 7.9636 | 0.01635 | 92.635 | 92.651 | 119.96 | 1006.65 | 1126.61 | 0.21830 | 1.8077 | 1.8640 | 152 |
| 153 | 4.0044 | 8.1632 | 0.01636 | 90.528 | 90.544 | 120.97 | 1006.06 | 1127.03 | 0.21994 | 1.8087 | 1.8620 | 153 |
| 154 | 4.1035 | 8.3648 | 0.01636 | 88.477 | 88.493 | 121.97 | 1005.47 | 1127.44 | 0.22157 | 1.8097 | 1.8600 | 154 |
| 155 | 4.2046 | 8.5607 | 0.01637 | 86.480 | 86.496 | 122.97 | 1004.88 | 1127.85 | 0.22320 | 1.8108 | 1.8580 | 155 |
| 156 | 4.3078 | 8.7708 | 0.01637 | 84.536 | 84.553 | 123.97 | 1004.29 | 1128.26 | 0.22482 | 1.8118 | 1.8560 | 156 |
| 157 | 4.4132 | 8.9853 | 0.01638 | 82.648 | 82.665 | 124.97 | 1003.70 | 1128.67 | 0.22645 | 1.8128 | 1.8540 | 157 |
| 158 | 4.5207 | 9.2042 | 0.01638 | 80.814 | 80.831 | 125.97 | 1003.11 | 1129.08 | 0.22807 | 1.8139 | 1.8520 | 158 |
| 159 | 4.6304 | 9.4276 | 0.01639 | 79.031 | 79.047 | 126.97 | 1002.51 | 1129.48 | 0.22969 | 1.8149 | 1.8501 | 159 |
| 160 | 4.7424 | 9.6556 | 0.01639 | 77.297 | 77.313 | 127.97 | 1001.92 | 1129.89 | 0.23130 | 1.8159 | 1.8481 | 160 |
| 161 | 4.8566 | 9.8882 | 0.01640 | 75.616 | 75.632 | 128.97 | 1001.33 | 1130.30 | 0.23292 | 1.8170 | 1.8462 | 161 |
| 162 | 4.9732 | 10.126 | 0.01640 | 73.985 | 74.001 | 129.97 | 1000.74 | 1130.71 | 0.23453 | 1.8180 | 1.8442 | 162 |
| 163 | 5.0921 | 10.368 | 0.01641 | 72.403 | 72.419 | 130.98 | 1000.13 | 1131.11 | 0.23614 | 1.8191 | 1.8423 | 163 |
| 164 | 5.2134 | 10.615 | 0.01642 | 70.866 | 70.882 | 131.98 | 999.54 | 1131.52 | 0.23774 | 1.8201 | 1.8404 | 164 |
| 165 | 5.3372 | 10.867 | 0.01642 | 69.375 | 69.389 | 132.98 | 998.94 | 1131.92 | 0.23935 | 1.8211 | 1.8384 | 165 |
| 166 | 5.4634 | 11.124 | 0.01643 | 67.924 | 67.940 | 133.98 | 998.35 | 1132.33 | 0.24095 | 1.8222 | 1.8365 | 166 |
| 167 | 5.5921 | 11.386 | 0.01643 | 66.514 | 66.530 | 134.98 | 997.75 | 1132.73 | 0.24255 | 1.8232 | 1.8346 | 167 |
| 168 | 5.7233 | 11.653 | 0.01644 | 64.770 | 64.786 | 135.98 | 997.16 | 1133.14 | 0.24414 | 1.8242 | 1.8328 | 168 |
| 169 | 5.8572 | 11.926 | 0.01644 | 63.398 | 63.398 | 136.99 | 996.55 | 1133.54 | 0.24574 | 1.8253 | 1.8309 | 169 |
| 170 | 5.9936 | 12.203 | 0.01645 | 62.069 | 62.085 | 137.99 | 995.95 | 1133.94 | 0.24733 | 1.8263 | 1.8290 | 170 |
| 171 | 6.1326 | 12.487 | 0.01645 | 60.710 | 60.726 | 138.99 | 995.36 | 1134.36 | 0.24892 | 1.8273 | 1.8271 | 171 |
| 172 | 6.2742 | 12.775 | 0.01646 | 59.430 | 59.439 | 139.99 | 994.76 | 1134.75 | 0.25051 | 1.8283 | 1.8253 | 172 |
| 173 | 6.4182 | 13.070 | 0.01647 | 58.169 | 58.184 | 141.00 | 994.15 | 1135.15 | 0.25209 | 1.8293 | 1.8234 | 173 |
| 174 | 6.5666 | 13.370 | 0.01647 | 56.944 | 56.960 | 142.00 | 993.55 | 1135.55 | 0.25367 | 1.8304 | 1.8216 | 174 |
| 175 | 6.7168 | 13.676 | 0.01648 | 55.750 | 55.766 | 143.00 | 992.95 | 1135.95 | 0.25525 | 1.8314 | 1.8197 | 175 |
| 176 | 6.8699 | 13.987 | 0.01648 | 54.588 | 54.604 | 144.00 | 992.35 | 1136.35 | 0.25683 | 1.8324 | 1.8179 | 176 |
| 177 | 7.0259 | 14.305 | 0.01649 | 53.460 | 53.476 | 145.01 | 991.75 | 1136.76 | 0.25841 | 1.8334 | 1.8161 | 177 |
| 178 | 7.1849 | 14.629 | 0.01650 | 52.341 | 52.357 | 146.01 | 991.14 | 1137.15 | 0.25998 | 1.8343 | 1.8143 | 178 |
| 179 | 7.3469 | 14.959 | 0.01650 | 51.250 | 51.276 | 147.01 | 990.54 | 1137.55 | 0.26156 | 1.8353 | 1.8124 | 179 |
| 180 | 7.5118 | 15.295 | 0.01651 | 50.203 | 50.220 | 148.01 | 989.93 | 1137.94 | 0.26312 | 1.8363 | 1.8106 | 180 |
| 181 | 7.6801 | 15.637 | 0.01651 | 49.173 | 49.190 | 149.02 | 989.32 | 1138.34 | 0.26468 | 1.8373 | 1.8089 | 181 |
| 182 | 7.8514 | 15.986 | 0.01652 | 48.168 | 48.185 | 150.02 | 988.72 | 1138.74 | 0.26625 | 1.8383 | 1.8071 | 182 |
| 183 | 8.0258 | 16.341 | 0.01652 | 47.187 | 47.204 | 151.02 | 988.12 | 1139.14 | 0.26781 | 1.8393 | 1.8053 | 183 |
| 184 | 8.2035 | 16.703 | 0.01653 | 46.229 | 46.246 | 152.03 | 987.50 | 1139.53 | 0.26937 | 1.8403 | 1.8035 | 184 |
| 185 | 8.3845 | 17.071 | 0.01654 | 45.294 | 45.311 | 153.03 | 986.89 | 1139.92 | 0.27093 | 1.8413 | 1.8017 | 185 |
| 186 | 8.5689 | 17.446 | 0.01654 | 44.381 | 44.398 | 154.04 | 986.28 | 1140.32 | 0.27248 | 1.8423 | 1.8000 | 186 |
| 187 | 8.7566 | 17.829 | 0.01655 | 43.489 | 43.506 | 155.04 | 985.67 | 1140.71 | 0.27404 | 1.8433 | 1.7982 | 187 |
| 188 | 8.9476 | 18.218 | 0.01656 | 42.618 | 42.634 | 156.04 | 985.07 | 1141.11 | 0.27559 | 1.8443 | 1.7965 | 188 |
| 189 | 9.1422 | 18.614 | 0.01656 | 41.766 | 41.782 | 157.05 | 984.45 | 1141.50 | 0.27713 | 1.8453 | 1.7947 | 189 |
| 190 | 9.3403 | 19.017 | 0.01657 | 40.932 | 40.948 | 158.06 | 983.84 | 1141.89 | 0.27868 | 1.8463 | 1.7930 | 190 |
| 191 | 9.5420 | 19.428 | 0.01658 | 40.118 | 40.135 | 159.06 | 983.22 | 1142.28 | 0.28022 | 1.8473 | 1.7913 | 191 |
| 192 | 9.7475 | 19.846 | 0.01658 | 39.322 | 39.339 | 160.06 | 982.61 | 1142.67 | 0.28176 | 1.8483 | 1.7896 | 192 |
| 193 | 9.9568 | 20.271 | 0.01659 | 38.543 | 38.560 | 161.06 | 982.00 | 1143.06 | 0.28330 | 1.8493 | 1.7878 | 193 |
| 194 | 10.169 | 20.704 | 0.01659 | 37.807 | 37.824 | 162.07 | 981.38 | 1143.45 | 0.28484 | 1.8503 | 1.7861 | 194 |
| 195 | 10.386 | 21.145 | 0.01660 | 37.069 | 37.086 | 163.08 | 980.76 | 1143.84 | 0.28638 | 1.8513 | 1.7844 | 195 |
| 196 | 10.606 | 21.594 | 0.01661 | 36.349 | 36.365 | 164.08 | 980.15 | 1144.23 | 0.28791 | 1.8523 | 1.7828 | 196 |
| 197 | 10.830 | 22.050 | 0.01661 | 35.643 | 35.660 | 165.08 | 979.54 | 1144.62 | 0.28944 | 1.8533 | 1.7811 | 197 |
| 198 | 11.058 | 22.515 | 0.01662 | 34.954 | 34.971 | 166.09 | 978.91 | 1145.00 | 0.29097 | 1.8543 | 1.7794 | 198 |
| 199 | 11.290 | 22.987 | 0.01663 | 34.281 | 34.298 | 167.10 | 978.29 | 1145.39 | 0.29250 | 1.8552 | 1.7777 | 199 |
| 200 | 11.526 | 23.468 | 0.01663 | 33.623 | 33.640 | 168.10 | 977.68 | 1145.78 | 0.29402 | 1.8562 | 1.7760 | 200 |
| 201 | 11.767 | 23.957 | 0.01664 | 32.980 | 32.997 | 169.11 | 977.06 | 1146.16 | 0.29554 | 1.8572 | 1.7744 | 201 |
| 202 | 12.011 | 24.455 | 0.01665 | 32.351 | 32.368 | 170.11 | 976.43 | 1146.54 | 0.29706 | 1.8582 | 1.7727 | 202 |
| 203 | 12.260 | 24.961 | 0.01665 | 31.737 | 31.754 | 171.12 | 975.81 | 1146.93 | 0.29858 | 1.8592 | 1.7711 | 203 |
| 204 | 12.513 | 25.476 | 0.01666 | 31.136 | 31.153 | 172.12 | 975.19 | 1147.31 | 0.30010 | 1.8602 | 1.7694 | 204 |
| 205 | 12.770 | 26.000 | 0.01667 | 30.549 | 30.566 | 173.13 | 974.56 | 1147.69 | 0.30161 | 1.8612 | 1.7678 | 205 |
| 206 | 13.031 | 26.532 | 0.01667 | 29.974 | 29.991 | 174.14 | 973.94 | 1148.08 | 0.30312 | 1.8621 | 1.7661 | 206 |
| 207 | 13.297 | 27.074 | 0.01668 | 29.413 | 29.430 | 175.14 | 973.32 | 1148.46 | 0.30463 | 1.8631 | 1.7645 | 207 |
| 208 | 13.568 | 27.625 | 0.01669 | 28.863 | 28.880 | 176.15 | 972.69 | 1148.84 | 0.30614 | 1.8641 | 1.7628 | 208 |
| 209 | 13.843 | 28.185 | 0.01669 | 28.326 | 28.343 | 177.16 | 972.06 | 1149.22 | 0.30765 | 1.8651 | 1.7613 | 209 |
| 210 | 14.123 | 28.754 | 0.01670 | 27.801 | 27.818 | 178.17 | 971.43 | 1149.60 | 0.30915 | 1.8660 | 1.7597 | 210 |
| 211 | 14.407 | 29.333 | 0.01671 | 27.287 | 27.304 | 179.17 | 970.81 | 1149.98 | 0.31065 | 1.8670 | 1.7581 | 211 |
| 212 | 14.696 | 29.921 | 0.01671 | 26.784 | 26.801 | 180.18 | 970.17 | 1150.35 | 0.31215 | 1.8680 | 1.7565 | 212 |

The method of calculating zero-pressure reduced entropy $s^o$ has been explained in the section on Zero-Pressure Properties of Water Vapor. The calculated values are purely relative; hence, it is necessary to add a constant adjusted to make $s_f = 0$ at 32 F. Since it is also desired to make $h_f = 0$ at 32 F, in conformity with steam table practice, the adjustment is accomplished by making $s_g$ calculated from Equation (30) for $p = p_s$ equal to $h_g/T$ calculated from Equation (16), both at 32 F, of course.

## Numerical Results

Final numerical results of the foregoing analysis are presented in the two tables following. Table 6 is for equilibrium between vapor and solid (ice) and covers the range −160 to 32 F. Table 7 is for equilibrium between vapor and liquid and covers the range 32 F to 212 F. The analysis itself contains all information necessary to compute corresponding tables giving the properties of compressed liquid (or solid) and those of superheated va-

por. Space limitations do not permit including such tables, however.

### Conclusions

The authors believe that the results of the present analysis accord with all experimental data used well within their estimated uncertainties. Possibly the results could be improved somewhat by considering other data outside the temperature range of present interest, but we doubt that the improvement would justify the enormous amount of labor involved.

The present formulation involves some revisions to the formulation on which tables presented in a previous paper [2] giving the thermodynamic properties of moist air were based. Such revisions are minor, however, and would not change the numerical values listed in the tables within their estimated uncertainties; they were made chiefly in the interest of consistency.

One of the most bothersome gaps in existing experimental data is the lack of precise knowledge of the relation between the absolute and the international temperature scales. This makes it impossible to state with complete definiteness on what scale the temperatures listed in Tables 6 and 7, for example, belong. For, while the zero-pressure properties were computed for temperatures on the absolute scale, they were used in conjunction with calorimetric data for temperatures on the international scale. Still, in many cases integration with respect to absolute temperature, or to the logarithm of absolute temperature, of an integrand whose values do not depend strongly on temperature was involved. In such cases the results are to be regarded as valid for temperatures on the absolute scale, even though the integrands were evaluated for temperatures on the international scale. This is true in the case of our calculated vapor pressures. It is hoped that the relation between the two scales will ultimately be defined more precisely by further experimentation. A necessary preliminary seems to be to improve the specifications for the international scale to insure a greater degree of reproducibility.

### Physical Constants and Conversion Factors

It seems appropriate to collect the numerical values of the various physical constants and conversion factors used in the preceding analysis.

| | |
|---|---|
| Pressure-volume product, pv (0°C, 0 atm): | $RT_o = 22414.6$ cm³atm/mole |
| Ice-point temperature: | $T_o = 273.16$ °K |
| Standard gravitational acceleration: | $g_o = 980.665$ cm/sec² |
| Density of Mercury (0°C, 1 atm): | $D_o = 13.59504$ g*/cm³ |
| Molecular weight of water: | $M_w = 18.0160$ g/mole |
| Second Radiation Constant: | $hc/k = 1.43848$ cm °K |

1.033223 kg/cm²atm
860 kcal/int (mean) kwhr
1.00020 abs kwhr/int (mean) kwhr
1 Btu kmol°K/kcal mol°/R

Universal Gas Constant: $R = 1.98581$ Btu/mol°R

2.54 cm/in
453.5924 g/lb
1.8 °R/°K
778.18 ftlb/Btu
1.000026 int (certified NBS) kwhr/int (mean) kwhr


### Acknowledgment

The present analysis was a necessary step in the formulation of the thermodynamic properties of moist air which was undertaken as a cooperative investigation with the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. The support and encouragement of the Society are gratefully acknowledged. The paper itself is submitted as a contribution from the University of Pennsylvania Thermodynamics Research Laboratory, and for the active support and encouragement of the Navy Department, Bureau of Ships, which have made the establishment of this laboratory possible it is a pleasure to acknowledge appreciation.


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**Instruments:** C. M. Ashley,* *Chairman;* Prof. L. M. K. Boelter, E. L Broderick, R. S. Dill, R. B. Engdahl, Lt. Col. A. P. Gagge, Dean John A. Goff,* Prof. R. C. Jordan, Prof. G. B. Priester, E. W. Rietz, W. R. Teller.

**Insulation:** Comdr. E. R. Queer, *Chairman;* R. E. Backstrom, T. H. Coulter, Prof. F. G. Hechler, H. E. Lewis, H. E. Robinson, T. D. Stafford, Capt. T. H. Urdahl,* Prof. G. B. Wilkes, P. M. Woodworth.

**Physiological Reactions:** R. W. Keeton, M.D., *Chairman;* Thomas Bedford, M.D., Capt. A. R. Behnke, Dr. A. C. Burton, E. F. DuBois, M.D., Lt. Col. A. P. Gagge, A. C. Ivy, M.D., Dr. D. H. K. Lee, F. C. McIntosh,* R. R. Sayers, M.D., Charles Sheard, M.D., Col. A. D. Tuttle.

**Psychrometry:** J. H. Walker, *Chairman;* Dr. H. C. Dickinson, Dean John A. Goff,* Prof. William Goodman, Prof. A. P. Kratz, D. M. Little, Prof. C. O. Mackey, W. E. K. Middleton, D. D. Wile.

**Radiation and Comfort:** J. C. Fitts, *Chairman;* R. E. Daly, Dr. F. E. Giesecke,* L. N. Hunter, Prof. F. W. Hutchinson,* John James,* Prof. A. P. Kratz, C. S. Leopold, E. M. Mittendorff, L. L. Munier, Dr. G. W. Penney, H. F. Randolph, W. R. Rhoton.

**Sensations of Comfort:** Thomas Chester, *Chairman;* R. S. Arnold, Prof. M. K. Fahnestock, G. D. Fife, Lt. Col. W. J. McConnell, F. C. McIntosh,* A. B. Newton, K. E. Robinson, Prof. C. P. Yaglou.

**Sorbents:** Comdr. John Everetts, Jr., *Chairman;* R. E. Cherne, O. D. Colvin, F. C. Dehler, L. S. Epstein, Dean John A. Goff,* C. H. B. Hotchkiss, J. C. Patterson, G. L. Simpson, C. F. Sines.

**Sound Control:** R. D. Madison, *Chairman;* C. M. Ashley,* Dr. P. H. Geiger, C. H. Hall, W. W. Kennedy, G. C. Kerr, E. W. McMullen, A. G. Sutcliffe, T. H. Troller, Capt. T. H. Urdahl,* Dr. T. A. Walters.

**Weather Design Conditions:** Capt. T. H. Urdahl,* *Chairman;* J. C. Albright, C. E. Bentley, R. E. Biller, H. S. Birkett, J. F. Collins, Jr., Comdr. John Everetts, Jr., J. P. Fitzsimons, Capt. J. D. Kroeker, Comdr. F. W. Reichelderfer, H. C. S. Thom.

*Member of Committee on Research, 1945.

## INSTITUTIONS COOPERATING WITH THE COMMITTEE ON RESEARCH

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
College Station, Texas
The Effect of Secondary Turbulence on the Friction in a Flowing Stream of Water

CASE SCHOOL OF APPLIED SCIENCE
Cleveland, Ohio
Air Distribution in Rooms
Heat Transfer Coefficients of Freon Refrigerants

CORNELL UNIVERSITY
Ithaca, New York
Periodic Heat Flow Through Composite Walls or Roofs

OREGON STATE COLLEGE
Portland, Oregon
Heat Transfer Through Wetted Walls

KANSAS STATE COLLEGE
Manhattan, Kansas
Projection of Heated and Cooled Air Streams
Experimental Studies of Radiant Heating and Cooling

UNIVERSITY OF CALIFORNIA
Berkeley, California
Air and Surface Temperatures in a Panel-Heated Room
The Measurement of the Radiant Effect in Heated and Cooled Rooms
Cooling Tower Design and Performance

UNIVERSITY OF ILLINOIS
Urbana, Illinois
Heat Losses Due to Infiltration

UNIVERSITY OF MINNESOTA
Minneapolis, Minnesota
Statistical Analysis of Variables Entering into Sensory Reactions to Summer Air Conditioning

UNIVERSITY OF TORONTO
Toronto, Ontario, Canada
Moisture Condensation on a Surface and the Measurement of the Dew-Point

## RESEARCH PAPERS—1945

1. The Transmission of Solar Radiation Through Flat Glass Under Summer Conditions, by George V. Parmelee (Cleveland) (October-November 1945, JOURNAL SECTION).

2. A New Friction Chart for Round Ducts, by D. K. Wright, Jr. (Cleveland) (October-November 1945, JOURNAL SECTION).

3. An Experimental Investigation of the Effect of Change in Atmospheric Conditions and Noise Upon Performance, by Morris S. Viteles, Ph.D. (Philadelphia) and Kinsley R. Smith, Ph.D. (State College) (to be published later).

4. Physiological Response of Subjects Exposed to High Effective Temperatures and Elevated Mean Radiant Temperatures, by Clark M. Humphreys (Cleveland), Oscar Imalis and Carl Gutberlet (Pittsburgh) (to be published later).

5. Effect of Branch Take-Off Design on Noise in Ventilating Duct Systems, by Oscar Imalis (Pittsburgh), F. C. Houghten (deceased) and Clark M. Humphreys (Cleveland) (to be published later).

6. The Shielding of Thermocouples from the Effects of Radiation, by George V. Parmelee and Richard G. Huebscher (Cleveland) (see this issue).

# 1945

# Annual Report

# Committee on Research

## Report of the Chairman—G. L. Tuve

THE RESUMPTION of peace-time activities has been gradual in Society Research as in other fields. But the research program has now more than attained its pre-war size. Much actual research was initiated during 1945, and even more significant were several improvements in organization and preparation for an enlarged future program. The Director of Research has built up an excellent staff, and through active planning with the Technical Advisory Committees each research project is being closely related to the needs of the Society membership. A desirable correlation has recently been established with the Guide Publication Committee, so that research results may be more rapidly converted into useful Guide data.

An important event in the year's program was the assignment by the U. S. Public Health Service of a senior engineer to the Society's Research Laboratory at Cleveland, to conduct studies in the relationship of air conditioning and ventilation to industrial hygiene.

### Committee Activities

The Society is distinguished for its extensive research committee organization. Almost 300 committee memberships are involved in the research program. Omission of the Society's 1945 Semi-Annual Meeting cancelled the most important opportunity for mid-year committee meetings. But a large volume of work has been done by mail, and no less than a dozen special meetings of committees have been held. A like number are scheduled for the 1946 Annual Meeting.

The attention of Society members will be focused at an early date upon the activities of two special committees authorized by Council, the Committee on Research Financing, of which Dr. A. C. Willard is Chairman, and the Committee on Housing, under the chairmanship of E. N. McDonnell, Chicago, Ill. An organization originally sponsored by the Committee on Research, but now independent of our Society, is the International Joint Committee on Psychrometric Data, of which J. Herbert Walker, Detroit, Mich., is Chairman. This group is making an outstanding study of research data, which will be of great value to the profession. Participating in this joint effort are twelve scientific and engineering organizations of the United States, Great Britain and Canada.

### Reports and Plans

A six-page *Research Reporter* was mailed in November to about 800 individuals and firms who have participated in financial or committee support of our research program. Plans for the 1946 program were briefly indicated, covering the nine projects in progress at the Laboratory in Cleveland, and 15 additional projects of ten cooperating institutions. About ten research papers have been completed during the year or are in preparation.

A budget of $110,000 per year for the next three years has been set as the goal for an adequate research program.

### Future Needs

The ASHVE research program calls for three steps: first, defining the problems on which research is needed; second, getting the work done, and third, making the results available in useful form. The nature of our Society demands that research be highly diversified, and the Committee on Research recognizes this need. But to complete these three steps for each of a wide variety of research projects calls for the utmost in cooperation from each and every member of the Society. Following are outlines of certain urgent needs in the carrying out of each of the three steps:

1. *Technical Suggestions:* Criticisms of the research program should be translated by Society members into positive technical suggestions for research on specific topics. Critics are welcomed on the Technical Advisory Committees, to help plan a well-rounded program.
2. *Cooperative Projects:* Assistance is needed in securing more cooperating research institutions. This will both diversify the program and make it more economical. Supervision and overhead are usually assumed by the cooperating institution, thus adding both personnel and resources to the Society program.
3. *Publications Program:* This is the most urgent need and the program should be supported by every member of the Society. It is suggested that research publications be of three types: (*a*) Each month the JOURNAL SECTION of the Society should carry short, practical research papers, giving data in useful and readable form. (*b*) Research Bulletins should be issued on all major projects, giving full data and results. Some of these would be reprints from the TRANSACTIONS. (*c*) A *Research Reporter* should be issued frequently, giving current news of the research program.

The Report of the Director of Research, which follows, includes summaries of the work of the Technical Advisory and other Committees.

# Report of the Director of Research—Cyril Tasker

## Introduction

The year 1945 has seen an expansion in the research activities of the Society, for, with increased staff, we were able to activate some of the programs planned during the war years.

We were also able to secure both instruments and equipment and our inventory of such items shows a marked increase over that of a year ago. The installation of workshop machinery also enabled us to build many pieces of equipment at the Laboratory.

*Staff*

Clark M. Humphreys returned to the Laboratory on September 1st and took over the post of Senior Engineer. Herbert B. Nottage joined the staff on July 1st; his experience in the field of heat transfer opens up possibilities for further work in this field. Dr. Allen D. Brandt, assigned to the laboratory by the U. S. Public Health Service, joined us in October. This assignment marked the commencement of active participation by the Society in the fields of industrial hygiene and ventilation.

The additions to our senior staff necessitated additional clerical help; we have kept in close touch with most of the Technical Advisory Committees and the cooperating institutions and our contacts with other workers have increased greatly. We still need additional junior staff and technical assistants and hope to add these early in 1946.

The writer hereby gratefully acknowledges the assistance rendered by all members of the staff in accelerating the research program during 1945. We also acknowledge the help given by the Secretary of the Society and the staff at the New York office.

## Guide Activities

The coordination of research activities with other technical activities of the Society came much nearer to realization during 1945. The President appointed the Director of Research as a member of the Guide Publication Committee and every senior member of the Laboratory staff assisted in the revision of Guide chapters during 1945. Some chapters were wholly rewritten by staff members; others were reviewed and data accumulated by the Research Laboratory made available for THE GUIDE. This cooperation and coordination is of the greatest importance to the future of the Society since THE GUIDE enables the results of Society and other research to be translated into practice.

## Industry Contacts, Liaison and Publicity

There was a marked increase in the number of visitors to the Laboratory. Some of the Technical Advisory Committees met there in October, and many members visited us at other times and discussed the programs under way. We also had visitors from England, official and unofficial, from Australia, Russia, and Sweden, while officers from the Canadian Department of Reconstruction made two visits to discuss our work on solar radiation transmission.

Though contacts by correspondence have greatly increased, we still lack the means whereby our research work may be effectively publicized and the results made known, in easily readable form, to every member of the Society and to the wider audience throughout the industry and among the general public. An attempt along these lines was made in October when a 4 page pamphlet, *The Research Reporter*, with a one page insert, "Research in Progress," was prepared at the Laboratory and distributed to some 400 organizations in the industry, to all officers of the Society, and to Committee members and officers of local chapters. The pamphlet *Research in Progress* was also distributed to the entire membership.

## Studies at the Laboratory and Cooperating Institutions

Rather than discuss the progress made at the Laboratory and the cooperating institutions according to the particular Technical Advisory Committees concerned, we have grouped the studies under a number of general headings. It is impossible, in a report of reasonable length, to give much beyond the barest outline, but the Laboratory staff will be pleased to supply further details to members and others interested if they will write or visit us.

## Air Flow, Distribution and Friction

In view of the importance to the industry of the items that may be classed under this general heading, it is encouraging to be able to report substantial activity during 1945. A sub-committee of the Technical Advisory Committee on Air Distribution and Air Friction met in March and formulated a program to cover a study of air friction in ducts. This resulted in a paper entitled, A New Friction Chart for Round Ducts, by Prof. D. K. Wright, Jr. (ASHVE JOURNAL SECTION, Oct.-Nov. issue). The new chart was submitted for acceptance by the Society and will appear in THE GUIDE 1946. It represents a considerable advance over charts previously used and is based on recent work in the field of fluid mechanics which produced data of high accuracy having general acceptance.

Other aspects of the overall problem of air friction in ducts and fittings such as comparisons for round, square and oblong ducts, friction through flow-in branches, take-off from trunks, etc., are receiving attention and additional results should be available during 1946.

*Barometric Dampers:* Studies of barometric dampers under the Technical Advisory Committee on Fuels were enlarged to include studies of the flow of gases in a duct-tee section containing a swinging damper. Studies of the torque-displacement for representative dampers have been completed and a progress report prepared; studies on the elements of the flow system are now in progress.

*Effect of Branch Take-off Design on Noise in Ventilating Duct Systems:* The results of a study made for the Navy Department during the war were presented at the 52nd Annual Meeting in a paper by Oscar Imalis, the late F. C. Houghten, and Clark M. Humphreys. The tests showed that: (*a*) The noise created by the splitter in a branch take-off arises from the turbulence of a relatively stationary mass of air back of the splitter. The noise can be reduced by properly streamlining the splitter. (*b*) Universally accepted standards of sound measurement techniques are badly needed in many phases of the ventilating and air conditioning industry and until such standards are available, the proper interpretation of sound measurements, and the correlation of the results of various investigators in the field, will be difficult or impossible.

*Cooperative Research*

1. *Case School of Applied Science:* The performance of diffusing type air outlets including wide-angle grilles and several sizes and types of perforated panels has been studied. Results, expressed in terms of dimensionless ratios, gave consistent curves when the residual velocity of the primary stream, expressed as a percentage of outlet velocity, was plotted against the distance from the discharge face in *equivalent diameters*. Instrumentation continues to be the major problem, and a better means for measuring room-air velocities is urgently needed.

Further work is now being done on the slot-type air outlet. With lower ceilings and little space for duct work and mixing zones, the location of multiple outlets on a long duct is becoming more common. Uniformity of air flow from all outlets of such an installation is a problem, whether the outlets are grilles, ceiling units, perforated panels or

simple slots. Hence the distribution of air to long slots or multiple outlets is also being studied.

2. *Kansas State College:* These studies were planned to determine the characteristics of downwardly projected streams of heated air, to study the pattern of flow and to set up practicable means for predicting the maximum downward travel of the air when the surrounding room air temperature, orifice temperature of the projected air, size and shape of orifice, and velocity of projected air at the orifice are known. The buoyancy force which resists the downward flow of heated air considerably complicates the problem.

Mathematical analyses have been made and experimental work carried on to obtain temperature and velocity traverses, at different levels, across a stream of heated air projected from an orifice located 23 ft above the floor. This work is actively in progress and we are indebted to Prof. Linn Helander for his keen interest in the problem.

## Industrial (Process) Ventilation

Since Dr. Brandt took up his assignment, substantial progress has been made in the task of collecting and correlating all available information on process ventilation from engineering schools, governmental industrial hygiene departments, insurance companies, equipment manufacturers, consulting engineers, etc. The replies to the questionnaires distributed serve to show how little detailed, factual and dependable information is available.

All existing codes, laws and ordinances relating to the control of occupational diseases are being collected with a view to their correlation and the preparation of a model code.

At the Laboratory a start has been made on the study of air flow into suction openings to determine the center line flow equation for small, plain, freely suspended hoods.

*Air Sterilization and Odor Control:* The Committee under Prof. W. F. Wells, formed in 1944, has been working with a sub-committee of the *American Public Health Association* to set up a procedure for making sanitary air surveys. With the background of recent studies made for the Armed Services, the Committee plans to proceed at once with studies in schools, auditoria, etc.

## Heat Flow and Heat Transfer

Under this general heading are classed studies under the Technical Advisory Committees on Glass, Heating Load, Cooling Load, Heat Transfer Surfaces, and Insulation. The comprehensive report, Heat Transmission through Windows and Glass Panels, prepared by G. V. Parmelee in 1944 has been under careful review by an editorial sub-committee prior to its publication as a special research bulletin. We hope to publish this early in 1946.

*Film Coefficients for Flat Surfaces:* Studies have been in progress during 1945 using equipment designed, and for the most part constructed, at the Laboratory. The main features are a draw-through type wind tunnel and a plate, four feet in length, which can be heated electrically by sections. Much of the experimental work has been completed and a report, Forced Convection Heat Transfer Coefficients along a Flat Surface, distributed for Committee study. A second report entitled, Relationship Between Skin Friction of a Smooth Flat Plate and Heat Transfer Coefficients, is nearing completion. Continuing studies are planned to determine the effect of widely spaced transverse ribs, (*e.g.*, muntin bars on a window).

*Solar Radiation Transmission through Glass:* A comprehensive program recommended by the Glass Committee was endorsed by the Technical Advisory Committee on Cooling Load. Special apparatus was designed and construction commenced in the early summer. It consists essentially of a 4 ft x 4 ft window frame pivoted on a horizontal axis, the whole being carried on a turntable. Heat transmitted by the window (or other glass surface) is absorbed by a water cooled section fastened to the rear side of the frame and the mechanism makes it possible to study the effect of the angle of incidence as well as the effects of both exterior and interior shading. Instrumentation and calibration are now under way; the equipment will be mounted in a suitable outside location so as to make studies under actual weather conditions.

Parallel with the design and construction of this apparatus a mathematical analysis was made of solar heat flow through all types of single and double glass. The results were published in JOURNAL SECTION, October-November, 1945, in the paper entitled, The Transmission of Solar Radiation Through Flat Glass Under Summer Conditions, by G. V. Parmelee.

New tables of solar radiation values, tables of the direct solar heat transmitted through single standard glass for various latitudes, and tables giving new data on shading factors were prepared for inclusion in the chapter dealing with Cooling Loads in THE GUIDE 1946.

*Heat Transfer of Refrigerants:* At Case School of Applied Science refrigerant-side heat transfer coefficients in duct coils and unit coolers are being studied by three methods. A large number of full-sized coils have been tested and individual air-side and refrigerant-side coefficients determined. Two other methods, however, have been found more effective for studying the heat transfer of the evaporating refrigerant. A long-tube counterflow evaporator was first constructed to study the evaporation in straight tubes. Then return bends were added. Finally, an electrically heated tube has been set up, using currents of 200 to 1200 amperes passed through the tube itself. Effects of return-bends are clearly shown by the temperature-gradient curves. Coefficients of heat transfer for evaporation of *Freon-12* with no special equipment for separating oil have been observed to range usually from 100 to 500 Btu per square foot per degree difference between saturation temperature and surface temperature, depending largely on load. A report on these studies will be available early in 1946.

*Periodic Heat Flow:* The mathematical analyses of heat flow through homogeneous walls and roofs, under way at Cornell University, were considered sufficiently complete to allow of their being extended to cover composite walls and roofs. A report on this phase is now before the Committee on Cooling Load. Prof. C. O. Mackey has also prepared a report on The Sol-Air Thermometer—a New Instrument, and is working on a simple method of presenting the essence of these studies for the determination of summer cooling loads within reasonable limits of accuracy. Subcommittees have been set up under the Committee on Cooling Load to deal with Appliances and Lights and Infiltration, and arrangements have been made to correlate all published work on periodic heat flow through homogeneous and non-homogeneous walls. Much remains to be done before usable, adequate data on periodic heat flow can be made readily available for the industry.

*Heating Load and Infiltration:* At the University of Illinois a survey of data taken in the I=B=R Research Home was made in an attempt to evaluate the effect of wind on the actual heat losses from the house. Fuel consumption curves for periods of the same average wind velocity were plotted against a range of average outdoor temperatures. In general the results indicated that for given indoor and outdoor temperatures the heat loss increased with increasing wind velocity up to a maximum velocity of about 9 mph. Between 9 and 15 mph the wind velocity seemed to have very little effect on the heat loss of the building. However, it was not possible to evaluate what portion of the total change in heat loss was a result of a change in infiltration rate and what portion was a result of change in the actual heat transmission through walls and glass. Other factors further complicated the analysis. Almost all published work to date serves to indicate how little we know about infiltration and how difficult is the problem of determining its effects on the heating load.

*Insulation:* Under the Committee on Insulation, a program has been initiated to obtain more accurate and dependable values of the thermal conductivity of insulating materials. All laboratories having equipment which conforms to the latest *ASTM* standards are being asked to cooperate in determining the thermal conductivity of test specimens of insulating material with the purpose of approving those laboratories whose results check those ob-

tained at the Bureau of Standards on the same sample. With a number of approved laboratories available, manufacturers may have their products tested under standardized conditions and users of the data thus obtained will have confidence in the results.

A final report on the studies at Oregon State College on Heat Transfer through Wetted Walls is in preparation. In general, the results indicated that with a wet wall and an air velocity of 15 mph the average coefficient U for the wall under test was 0.318, an increase of 12 per cent over the coefficient for the dry wall with a 15 mph wind, and an increase of almost 32 per cent over that for the dry wall under still air conditions.

## Environment, Comfort, Health and Efficiency

*Navy Studies:* The results of two studies made for the Navy Department during the war were released for publication and are being presented at the 52nd Annual Meeting.

The first is An Experimental Investigation of the Effect of Change in Atmospheric Conditions and Noise upon Performance, by Dr. Morris S. Viteles, Department of Psychology, University of Pennsylvania, and Dr. Kinsley R. Smith, Department of Psychology, Pennsylvania State College. The tests were designed to ascertain the effects of various atmospheric conditions and noise levels on the accuracy, variability and volume of work that young men could perform in confined spaces on naval ships. The findings suggested that there was no need to provide equipment for the reduction of Effective Temperatures below the 80 deg level, with some evidence that it may be undesirable to attempt work, of the type studied, at Effective Temperatures as high as 87 deg. It was also indicated that it was unnecessary to spend large sums to reduce noise to below the 90 db level. In general it was shown that the effect of high temperatures on performance is much more adverse than that of high levels of noise.

The second paper, Physiological Effects of High Effective Temperatures and Elevated Mean Radiant Temperatures, by Clark M. Humphreys, Oscar Imalis and Carl Gutberlet gives data indicating that within a wide range of environmental conditions all variables in a man's environment which affect his physiological reactions may be expressed in terms of Effective Temperature and mean radiant temperature elevation. The studies also showed that the effect of radiant heat on physiological reactions decreases as the Effective Temperature increases and becomes surprisingly small as the upper limits of endurability are reached. By repeated exposure to hot environments a person can acquire a considerable degree af acclimatization.

*Other Studies:* There have recently been made available several reports of studies made during the war for and by the Armed Services of the United States and its allies. Some contain information of direct interest and importance to heating, ventilating, and air conditioning engineers and preliminary steps have been taken towards an analysis of these reports with a view to summarizing their practical implications. The task is by no means easy but the results should justify the time and expense involved. Enormous sums of public money have been spent and there is no better body than the Society to make the results available for practicing engineers.

## Radiant Heating and Cooling

Studies on radiant heating and cooling have, unfortunately, had to take a back place during the past two years because of the demand of high priority war studies.

The cooperative research work at the University of California has resulted in five reports published in the ASHVE JOURNAL SECTION, in 1942, 1943 and 1944. In these the relationships existing between mean radiant temperature, surface temperature, shape moduli and related factors were discussed. In a paper to be presented at the 52nd Annual Meeting, Prof. F. W. Hutchinson reviews the complex rational design procedure presented in previous papers and proposes a single-equation design procedure for radiant heating systems.

A cooperative research project was initiated at Kansas State College during the year, the long range purpose of which is to study the relation between radiant heating and cooling, and human comfort and well-being. The immediate limited objectives are: (*a*) To determine the thresholds of human comfort when the boundary surface temperatures of a room are one of the controllable, variable factors contributing to human comfort or discomfort, and (*b*) To investigate means for determining mean radiant temperatures.

A psychrometric room has been designed and partially constructed, and most of the equipment necessary for operating the room and obtaining test data secured. It is planned to study the effect of cold and warm spots in walls, floors and ceilings and the manner in which one may compensate for such non-uniformities in surface temperatures.

At the Research Laboratory we have concentrated on the design of our new psychrometric rooms and are ready to proceed with their construction as soon as circumstances permit. A number of those participating in the Research program have earmarked their contributions for studies in radiant heating.

## Miscellaneous Studies

1. *Psychrometry:* At the University of Toronto, studies have been under way on the measurement of the dew-point of air-water vapor mixtures and the development of a dew-point hygrometer to provide a standard for the correlation of psychrometric data. This is a piece of fundamental research work but the results may have wide practical applications for it is generally agreed that our present methods of psychrometric instrumentation are far from satisfactory. An extensive review of the literature was made prior to the commencement of experimental work.

2. *Temperature Measurement:* A short paper entitled, The Shielding of Thermocouples from the Effects of Radiation, was prepared for presentation at the 52nd Annual Meeting. The tests indicated that random air currents can greatly affect the stability of readings of fine wire thermocouples in the presence of sources of radiation and that even shielding may not be wholly satisfactory. An aspirated thermocouple gives the true air temperature under most conditions.

*Flow of Fluids:* Studies are in progress at Texas A and M College to determine the increase in the friction in a stream of water flowing in a pipe and resulting from additional or secondary turbulence produced in the stream of water at the entrance of the pipe; for example, when, in a central hot water heating system, a 6-in. circulating pump is connected to a 12-in. flow main. In the present studies 4-in. pipe is being used and the connections between the pump and the pipe are being varied in size from ¾ in. to 2 in.

In the preceding paragraphs we have mainly discussed those studies which have progressed far enough during 1945 for papers to be prepared for presentation before the Society or for progress reports to be available for Committee study. Much additional work has been done and many other Committees have carried their studies to the stage where Laboratory projects can be initiated early in 1946. The Committee on Air Cleaning is studying the very difficult problem of standard tests for air cleaning devices and finding no general agreement as yet on the composition of a standard dust for this purpose. The Committee on Corrosion has undertaken to prepare a chapter on corrosion for THE GUIDE, 1947. The Committee on Sorbents has gathered a great deal of data collected on the subject and is now correlating it for GUIDE use. The Committee on Heat Transfer Surfaces has tentatively approved a comprehensive program of fundamental research work on heat transfer of finned tubes, but important details are still to be worked out. The Committee on Weather Design Data has agreed on the basis for a statistical analysis of a great deal of data collected a few years ago, and plans to make the analysis as soon as competent personnel and sorting equipment are available.

The work ahead of us is sufficiently well defined to ensure a continuous program during 1946—some new projects will be set up early in the year and many of the projects active during 1945 will be brought to the report stage during 1946.

## STATEMENT OF INCOME AND EXPENSES

### For the Fiscal Year Ended October 31, 1945

| | | | |
|---|---|---|---|
| **INCOME** | | | |
| *From A.S.H.V.E.* | | | |
| 40% of 1945 and prior years dues collected | | $24,630.65 | |
| Special Council appropriation | | 10,000.00 | |
| | | | $34,630.65 |
| *Contributions—Per Schedule* | | | |
| General | | $ 8,361.59 | |
| Earmarked | | | |
| Contributions received | $11,450.00 | | |
| Add: Deferred from prior year | 1,033.25 | | |
| | $12,483.25 | | |
| Less: Deferred to future operations | 3,063.37 | | |
| | | 9,419.88 | |
| Navy Contract | | 1,600.00 | |
| | | | 19,381.47 |
| *Interest from Bank Deposits* | | | 50.82 |
| TOTAL INCOME | | | $54,062.94 |
| **EXPENSES** | | | |
| *Chairman and Committee* | | | |
| Traveling | $ 608.02 | | |
| Chairman's Office | 340.45 | | |
| Professional Services | 250.00 | | |
| | | $ 1,198.47 | |
| *Research Laboratory* | | | |
| Salaries—Administrative and Technical | $21,490.52 | | |
| Salaries—Clerical | 5,088.60 | | |
| Traveling | 1,862.41 | | |
| Postage | 362.51 | | |
| Telephone and Telegraph | 621.30 | | |
| Office Expenses and Supplies | 585.03 | | |
| Printing and Mimeographing | 572.72 | | |
| Library and Periodicals | 255.99 | | |
| Laboratory Materials and Supplies | 3,465.83 | | |
| Depreciation — Equipment and Fixtures | 1,239.37 | | |
| Unallocated | 337.77 | | |
| Taxes (Cleveland rent) | 2,180.00 | | |
| Property Insurance | 168.40 | | |
| Heating | 649.47 | | |
| Electricity | 394.98 | | |
| Gas | 49.72 | | |
| Water | 15.54 | | |
| Janitor | 1,274.09 | | |
| Building Maintenance | 83.70 | | |
| | | 40,697.95 | |
| | | $41,896.42 | 54,062.94 |
| *Cooperative Research* | | | |
| University of California | $ 800.00 | | |
| University of Minnesota | 900.00 | | |
| Case School of Applied Science | 2,000.00 | | |
| Oregon State College | 400.00 | | |
| Texas A and M College | 375.00 | | |
| Kansas State College | 1,833.33 | | |
| University of Toronto | 1,307.20 | | |
| University of Illinois | 300.00 | | |
| State University of Iowa | 333.33 | | |
| | | 8,248.86 | |
| Navy Contract | | 1,600.00 | |
| *Special Council Appropriation* | | | |
| Expenditures for Laboratory Equipment, etc., charged against Council Appropriation | | 5,862.42 | |
| | | | 57,607.70 |
| EXCESS OF EXPENSES OVER INCOME | | | $ 3,544.76 |

## PARTICIPATING IN 1945 RESEARCH PROGRAM

Aerofin Corp.
**Airtemp Div. of Chrysler Corp.
*AGA Testing Laboratories
Allegheny County Steam Heating Co.
Aluminum Co. of America
**American Blower Corp.
*Anemostat Corporation
ASHVE-Michigan Chapter
Barnes & Jones, Inc.
Bethlehem Steel Co.
*Blue Ridge Glass Corp.
**Buffalo Forge Co.
Burnham Boiler Corp.
Brunner Manufacturing Co.
**Byers Co., A. M., The
Carrier Corp.
**Chamberlin Co. of America
Chicago Pump Co.
Chase Brass & Copper Co.
Crane Corp.
Dallas Engineering Co.
*Detroit Edison Co.
Dole Valve Co.
Duquesne Light Co.
Dunham Company, C. A.
Elliott Electric Co.
*Heating, Piping and Air Conditioning Contractors National Association*
Forslund Pump & Machinery Co.
Frick Co., Inc.
*Friez Instrument Co. (Bendix Corp.)
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Graphite Products Corp.
Hays Corp.
Hoffman Specialty Co., Inc.
*Holcomb & Hoke Mfg. Co.
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Kinetic Chemicals, Inc.
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Kewanee Boiler Corp.
*La-Del Conveyor & Mfg. Co.
*Libbey-Owens-Ford Glass Co.
Mahon Company, R. C., The
Marsh Company, The
McDonnell & Miller, Inc.
McQuay, Inc.
Mellish & Murray Co.
*Narowetz Heating & Ventilating Co.
National Radiator Co.
*National Mineral Wool Association*
Nash Engineering Co., The
**Nesbitt, John J., Inc.
*Owens Corning Fiberglas Corp.
*Perfex Corp.
*Pittsburgh Plate Glass Co.
*Pipe Fabrication Institute*
*Portland Cement Association*
Pyle-National Co., The
Raisler Co., The
*Russell, F. C., Co., The
*Sarco Co., Inc.
*Sarcotherm Controls, Inc.
Sisalkraft Co., The
Spencer Thermostat Co.
Sturtevant, B. F., Co.
Star Electric Motor Co.
Surface Combustion Corp.
Taylor Instrument Companies
Timken-Detroit Axle Co.
*Trade-Winds Motorfans, Inc.
U. S. Steel Corp.
Warren Webster & Co.
Weil-McLain Co.
Webster Engineering Co.
*Webster Electric Co.
Wheeler, W. H., Inc.
Williams Oil-O-Matic Heating Corp.
Wing, L. J., Mfg. Co.
Wood Conversion Co.
*Worthington Pump & Machinery Corp.
York Corp.
*Young Radiator Co.

*Earmarked Participation.
**Combination of Earmarked and General Participation.

# The Shielding of Thermocouples from the Effects of Radiation

By George V. Parmelee* and Richard G. Huebscher,** Cleveland, Ohio

This paper is the result of research carried on by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS at the Research Laboratory located at 10700 Euclid Avenue, Cleveland, Ohio

## Purpose

THIS REPORT presents the results of a study which was made to determine how effectively shields might reduce the effects of radiation on thermocouples used to measure room air temperatures. The need for such quantitative data arose during the construction at the ASHVE Research Laboratory of apparatus designed to measure the transmission of solar heat through glass. It was desired to measure accurately the temperature of the air within a 25 cu ft space enclosed by blackened sheet metal and a panel of glass under test. During a test the thermocouples would be subjected not only to the radiating influence of the sun but also to that of the glass, the temperature of which might differ considerably from that of the enclosed air. It was anticipated that the temperature of the metal surfaces would be within a few degrees of that of the air.

No extensive literature search was made, although, undoubtedly, this problem has often been discussed before. Information found in a book on temperature and its measurement[1] dealt, for the most part, with the temperature measurement of hot gases flowing through flues, and suggested the use of aspirated and shielded couples of various types. In the apparatus mentioned simplicity of installation and avoidance of air movement, other than that created by natural means, were considered sufficiently important to warrant some method of shielding. It was believed that a more useful purpose would be served by presenting the results of this investigation at the present time rather than including them in a longer report at a later date. Although the scope of the investigation was limited, such data as were obtained established some quantitative relationships that may be of value to others meeting similar problems.

Fig. 1—Apparatus for determining effectiveness of thermocouple shields

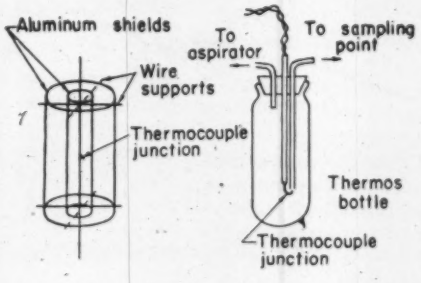


Fig. 2—Thermocouple shields

Fig. 3—Aspirated thermocouples

## Experimental Apparatus

Preliminary studies, made with direct sunlight indoors and with several different arrangements for shielding the thermocouples, led finally to the construction of the apparatus shown schematically in Fig. 1. In the tests herein discussed, the radiating source consisted of a cone type heater element operating at a red heat (wire at approximately 1600 F and ceramic at 1100 F). A cardboard enclosure surrounded the thermocouples under test and cardboard radiation shields were placed between the source and the enclosure. Therefore, with the exception of the small heater all surfaces seen by the thermocouples were substantially at air temperature.

True air temperature was measured by means of an aspirated thermocouple placed inside a thermos bottle (see Fig. 3). The sampling hose was of short length so as to reduce the possibility of temperature change of the air between the sampling point and the thermocouple. A small air disturbance was created in the enclosure by the device but was found to be negligible in its effect on the thermocouples under test. Temperatures were measured with a probable accuracy of ±0.15 F. The combined sensitivity of the measuring equipment was about ±one microvolt (0.05 F).

The thermocouples were made from No. 36 AWG copper and No. 30 AWG constantan wires which had previously been carefully calibrated. The junctions were only slightly larger than the wire itself and were soft soldered.

All shields were two inches long and were constructed from aluminum sheets of 0.006 in. thickness. The shield construction is shown in Fig. 2. Stiff wire supports were passed through holes in the shields as shown in the figure and were glued at their intersections with each other and with the shields with a cement used in model airplane construction. The longitudinal joint of the shield was also

*Research Fellow, ASHVE Research Laboratory, Member of ASHVE.

**Assistant Research Engineer, ASHVE Research Laboratory.

[1]Temperature, Its Measurement and Control in Science and Industry, Reinhold Publishing Co., New York, 1941.

Presented at the 52nd Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, New York, N. Y., January, 1946.

cemented, and the whole structure was suspended vertically by gluing the thermocouple wire to the wire supports.

The source of these sheets is not known, but evidently they had had several years exposure to the atmosphere, as indicated by their oxidized appearance. However, they still retained a fair reflectivity for light and no attempt was made to polish them. Edwards[2] has shown that long exposure affects only slightly the reflectivity of aluminum foil as regards infra-red radiation. The decrease in reflectivity for visible radiation is slightly greater. It is doubtful if appreciably different results would have been obtained by using more highly polished metal foil.

### Procedure

Each test consisted of a comparison between one shielded thermocouple and one unshielded couple with the result that no direct comparison between tests could be made on a temperature basis.

Temperature readings were taken first with the radiation source out of view of the opening in the enclosure and then continued with the source placed as shown in Fig. 1. After steady state conditions were reached, the hot body was removed and the temperature readings were continued for a short time thereafter. Temperature-time curves were plotted so as to determine the most representative temperature values for the test and also to establish the time response of the shielded and unshielded couples.

In order to compare the similarity of the various thermocouples used in the tests they were placed in the air blast from a small fan. Both shielded and unshielded couples then indicated exactly the same temperature.

### Observations

The results obtained are given in Table 1. However, some discussion of the various factors involved can well be made here, together with certain observations which were made during the tests but which cannot readily be tabulated.

The temperature of an unshielded thermocouple is determined by the balance between radiation gain and convective heat loss if conduction from the junction be neglected.[3] The radiant gain is affected by the temperature of the radiating objects and by the area and emissivity of the thermocouple. The convective heat loss is affected by the convective area of the thermocouple, the temperature difference between it and the ambient air, the size of the junction, and the air velocity over it. By making the junction of very small size in order to increase the rate of convective heat loss, or by making it a good reflector of radiation, or by passing air over it at high velocity, or by a combination of these methods, a thermocouple can be made to indicate very nearly the true air temperature. At best, however, a thermocouple can dissipate heat received by radiation only by means of a finite temperature difference, however small, between it and the air.

A single shield placed around the thermocouple reflects some of the incident radiation, the amount depending upon its surface character, and absorbs the rest. Part of this is reradiated to cooler objects including the thermocouple itself and the balance is dissipated by convection. If a series of concentric shields is used, the likelihood that heat will be radiated to the couple from the inner shield is reduced, while the convective area is increased, particularly if there is good conduction along the shields from the area receiving the radiation. Increasing the shield diameter tends to increase the ratio of convective area to radiation receiving area, but at the same time tends to decrease the unit rate of convective heat transfer. Increasing the length also reduces the unit rate of heat transfer. The actual construction required, of course, depends upon the nature of the radiating sources which may affect the thermocouple.

From theoretical considerations it would be expected that the temperatures of concentric shields would progressively decrease from outside to inside and that only in the ideal case would the innermost shield be at the same temperature as the thermocouple it enclosed. This was found to be true as shown by the following data taken in Test 6.

| Temperature—Deg F | |
|---|---|
| Outer shield | 81.1 |
| Inner shield | 80.7 |
| Shielded thermocouple | 80.3 |
| The air | 79.5 |
| Unshielded thermocouple | 80.8 |

If concentric shields are placed too close together and/or the thermocouple junction is too close to the inner shield, shielding may become a positive detriment. This is borne out in part by Test 1a where the shielded couple indicated a higher temperature than the unshielded. Evidently the junction was not only located in the convection current adjacent to the inner shield but also the temperature of this shield was greater than if the spacing of the three had been increased. This is in agreement with the well known fact that the conductance of an air space increases rapidly as the width of the space decreases. The small diameter shield in effect simply increases the diameter of the junction.

In the preliminary studies random air currents caused the galvanometer to fluctuate widely. With the instruments used these fluctuations were as great as ±15 microvolts ±(0.7 F). However, in a test

[2] Some Reflection and Radiation Characteristics of Aluminum, by J. D. Edwards and C. S. Taylor, (ASHVE TRANSACTIONS, Vol. 45, 1939, p. 179.)

[3] Heat Transmission, by W. H. McAdams (Second Edition, McGraw-Hill Publishing Co., New York, 1942, pp. 223-225.)

**Table 1—Summary of Test Results**

| Test No. | 1a | 1b | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shielding Arrangements | | | | | | | | | | | |
| Number | 3 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| Dia.—In. | ½,¾,1 | 1 | 1 | 2 | 2 | 3 | 2,3 | 1,2 | 1,2 | 1.2 | 1,2,3 |
| Temperature Indicated by Thermocouples Deg F | | | | | | | | | | | |
| Aspirated | 79.1 | 79.1 | 78.0 | 77.6 | 78.3 | 78.7 | 79.5 | 70.0 | 76.2 | 77.6 | 75.9 |
| Shielded | 81.6 | 80.6 | 79.5 | 78.6 | 79.6 | 79.9 | 80.3 | 71.8 | 77.6 | 78.9 | 77.1 |
| Unshielded | 81.2 | 81.2 | 79.8 | 79.0 | 80.7 | 80.4 | 80.8 | 72.6 | 78.4 | 79.9 | 77.8 |
| Error in Reading Referred to Aspirated Couple | | | | | | | | | | | |
| Unshielded | | | | | | | | | | | |
| Deg F | 2.1 | 2.1 | 1.8 | 1.4 | 2.4 | 1.7 | 1.3 | 2.6 | 2.2 | 2.3 | 1.9 |
| Per cent | 2.7 | 2.7 | 2.3 | 1.8 | 3.1 | 2.2 | 1.6 | 3.7 | 2.9 | 3.0 | 2.5 |
| Shielded | | | | | | | | | | | |
| Deg F | 2.5 | 1.5 | 1.5 | 1.0 | 1.3 | 1.2 | 0.8 | 1.8 | 1.4 | 1.3 | 1.2 |
| Per cent | 3.2 | 1.9 | 1.9 | 1.3 | 1.7 | 1.5 | 1.0 | 2.6 | 1.8 | 1.7 | 1.6 |
| Ratio of Error Shielded to Unshielded | 1.2 | 0.71 | 0.83 | 0.72 | 0.54 | 0.71 | 0.62 | 0.69 | 0.64 | 0.57 | 0.62 |

[a] Average of five tests.

made in direct sunlight indoors, the one inch O.D. triple shielded couple gave results similar to those listed under 1a of Table 1.

It was, therefore, found necessary to enclose the thermocouples under test and also to use the shields shown in Fig. 1 to prevent warm air currents generated by the radiant source from reaching the enclosure. There was later found to be an interchange of heat energy between the unshielded thermocouples and the outer shield of the shielded thermocouples. This effect was reduced by means of a cardboard barrier placed between them as shown by the dotted lines in Fig. 1. This shield was used in tests 2, 7, 8, and 9.

Depending upon the conditions within the test room, the aspirated couple gave temperature indications either equal to or below that of the junctions inside the cardboard enclosure. When the hot source was placed in front of the enclosure, there was a lapse of about 15 minutes before there was a constant difference between the aspirated thermocouple and the others, which, of course, responded much more rapidly.

Readings of each were taken at definite time intervals and the data plotted on time-temperature coordinates. The data given in Table 1 were taken from these curves at the point where they became parallel. Therefore, in spite of the fact that the temperature level rose during a test due both to the radiant source and the building heating system, the results are considered to be reliable.

Included with the thermocouples of tests 1a and 1b was one made of calibrated No. 24 AWG wires. The junction was unshielded and, as would be expected, it indicated a temperature greater than that of the fine wire couple, in this case 0.4 F.

### Conclusions

1. Random air currents can greatly affect the stability of readings of fine wire thermocouples and also those of wire as large as No. 24 gage. Use of a suitably sized shield seems desirable if for no other reason than to give stable readings.

2. In the absence of random air currents and in the presence of a body radiating at a temperature greater than that of the ambient air, the unshielded fine wire thermocouple indicated a temperature greater than the true air temperature.

3. The temperature of the shielded thermocouple which could see the radiant heat source was always greater than the true air temperature.

(a) The concentric group of shields with the maximum diameter equal to one inch, gave thermocouple readings exceeding that of the unshielded fine wire thermocouple. This indicates that a temperature responsive element should be at least one-half inch away from the nearest shield.

(b) When a single shield of one inch diameter or greater was used, the per cent error decreased as the diameter of the shield increased. The error, referred to true air temperature, was for all such cases, less than that of an unshielded thermocouple. Based on the data of Table 1, the optimum diameter is about two inches.

(c) Two concentric shields with the inner diameter one inch or greater still further reduced the error of the thermocouple reading.

(d) Three concentric shields with the inner diameter one inch showed no improvement over either double concentric shield which was tested.

4. If it is necessary to determine the difference in temperature between a surface and the ambient air with a small percentage of error, even the use of shielding devices may not be satisfactory. If general air movement cannot be tolerated, an aspirated thermocouple seems to be the most satisfactory device to secure true air temperature.

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## ERRATA

In the paper, A New Friction Chart for Round Ducts, by D. K. Wright, Jr., published on page 577 of the October - November 1945 ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, the author calls attention to an error in Equation (1). The correct expression of this Equation should be as follows:

If

$$h = f \frac{L}{D} \frac{V^2}{2g}$$

## ASRE ELECTS OFFICERS AT 41ST ANNUAL MEETING

A record crowd of members and guests attended the 41st Annual Convention of the *American Society of Refrigerating Engineers*, December 10-12, at the Hotel Pennsylvania, New York, N. Y., despite travel and hotel restrictions.

The following officers were elected to serve for the ensuing year: *President*—C. S. Leopold, consulting engineer, and chairman of ASHVE's Guide Publication committee, Philadelphia, Pa.; *Vice-Presidents*—R. H. Money, The Reynolds Metals Co., Louisville, Ky., and C. F. Holske, Vilter Mfg. Co., New York, N. Y. *Treasurer*—Prof. B. H. Jennings, Northwestern Technological Institute, Evanston, Ill., and member of Society's TAC on Air Sterilization and Odor Control.

*Directors* include: J. G. Bergdoll, York Corp., York, Pa.; H. C. Diehl, The Refrigeration Research Foundation, Berkeley, Calif.; Prof. R. C. Jordan, University of Minnesota, Minneapolis, Minn., who has presented numerous papers before the ASHVE; Dr. Mary E. Pennington, consulting engineer, New York, N. Y.; A. B. Schellenberg, formerly president of Alco Valve Co., St. Louis, Mo.; E. K. Strahan, Sr., E. K. Strahan, Inc., New Orleans, La.; and W. S. Woodside, United Cork Companies, Baltimore, Md.

During the meeting, Dr. A. W. Ewell, director, Physics Dept., Worcester Polytechnic Institute, and consulting engineer for Westinghouse Electric Corp., Bloomfield, N. J., was made a life member of the *ASRE*.

## DRAYER-HANSON BUYS NEW PLANT

Drayer-Hanson, designers and manufacturers of heat exchange equipment, have recently acquired a new factory and offices at 3301 Medford St., Los Angeles, Calif., covering an area of approximately seven acres. This includes 110,000 sq ft of manufacturing space with all machinery and equipment, and a railroad spur extending into the plant, plus 6000 sq ft office space.

Arrangements have been made to set up mass production lines for the complete line of standard commercial refrigeration coils, fabrication of evaporative condensers, shell and tube coolers, etc.

Also to be manufactured at the new plant are the new electrically operated, completely automatic, summer-winter air conditioner, and a portable cooling tower for the oil industry.

# Society Holds 52nd Annual Meeting in New York

## HOTEL COMMODORE

### January 27-30, 1946

Dr. C.-E. A. Winslow
New Haven, Conn.

AT THE 52nd Annual Meeting of the Society in Hotel Commodore, New York, N. Y., January 27-30, 1946, the members approved a new charter, voted to change the nominating committee procedure, and adopted a revision in the method of handling funds, and discussed 10 technical papers during the four sessions.

Of the 725 who registered, 514 were members of the Society, and 77 ladies were present.

Dr. C.-E. A. Winslow, president of the Society, conducted the business session and opened the first technical session when R. C. Cross, Chicago, Ill., presented his paper on, A Study of Several Coal-Fired Magazine-feed Space Heaters, in which he gave the results of performance tests of typical units to determine the advantages and disadvantages of the basic operating principles. He summarized the findings of his investigations and indicated that future developments may lead to considerable improvement in this type of equipment.

Orion O. Oaks, Raritan, N. J., gave his paper on, The Application of High Temperature Liquid as a Heat or Energy Transfer Medium for Domestic and Industrial Uses, in which he pointed out that it would be entirely practical for a home owner to have a one-fuel burning device which would furnish the energy for house heating, hot water, refrigeration, cooking, baking, ironing, and generating electricity for lighting and other purposes.

The subject of radiant heating was of great interest to the members present and Prof. F. W. Hutchinson, Lafayette, Ind., gave his paper on, A Single-Equation Design Procedure for Radiant Panel Systems. He explained the somewhat complex relationships which must be considered in the calculation of these designs, and he gave a relatively simple formula for the use of the busy engineer.

At the second technical session, Tuesday afternoon, Dean John A. Goff, Philadelphia, Pa., gave his paper on, Low-Pressure Properties of Water from —160 to 212 F. This described a comprehensive study of the properties of moist air and the paper presented data to improve currently used tables on spectroscopic constants, enthalpy and entropy at zero pressure, enthalpy coefficients, and vapor pressure of ice.

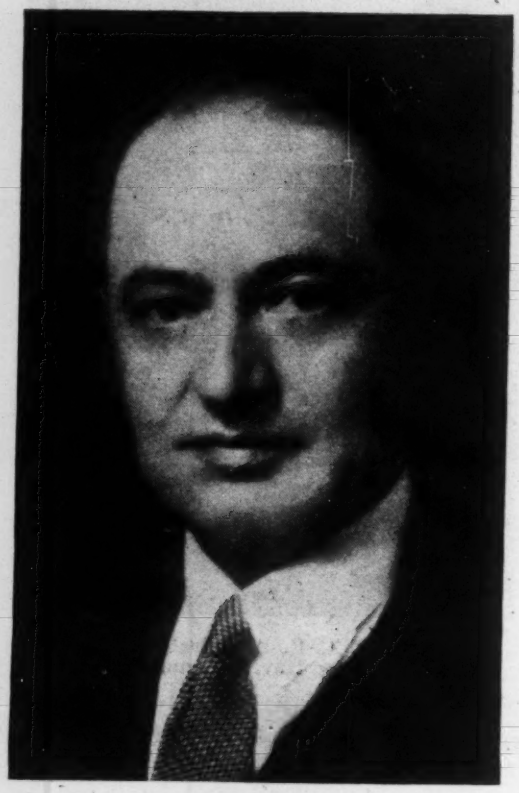
F. M. Allen, M.D., New York, N. Y., described the Therapeutic Uses of Low Temperature, and outlined some of the work that he had done on surgical anesthesia, infection, wounds, shock, burns, etc. He gave data based on his own experiences as well as references to literature on the subject which was of intense interest to his audience.

The Heating and Ventilating for Transport Airplanes was the subject of B. M. Brod, New York, N. Y., who described the heating and ventilating systems for aircraft, and discussed the problems involving the heating and ventilating and air conditioning in pressurized cabins, and the problems of humidity. He described the heating systems and the controls involved, as well as the methods of air distribution.

At the Wednesday morning session, the Report of the Committee on Research was presented by Prof. G. L. Tuve, and the four papers sponsored by the Society's Research Laboratory were presented. C. M. Humphreys, Senior Engineer, Research Laboratory, presented two of these papers, the first entitled, Effect of Branch Take-Off Design on Noise in Ventilating Duct

# OFFICERS FOR 1946

A · S · H · V · E ·



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President

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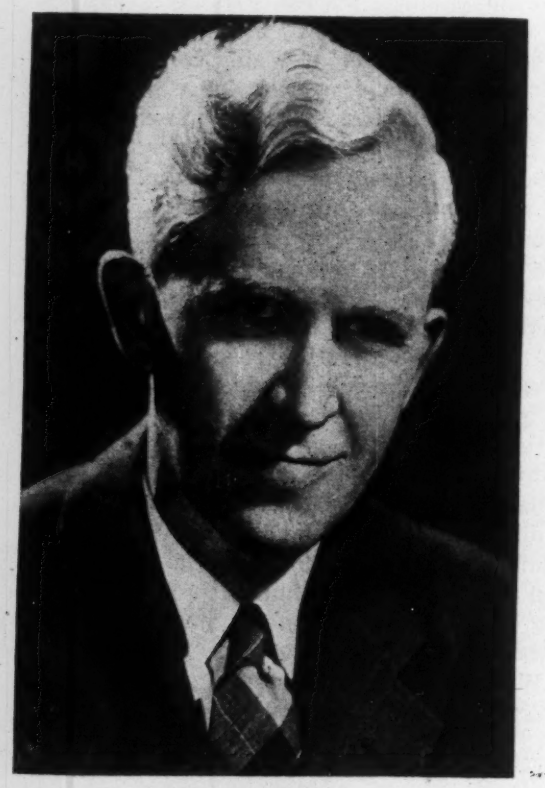
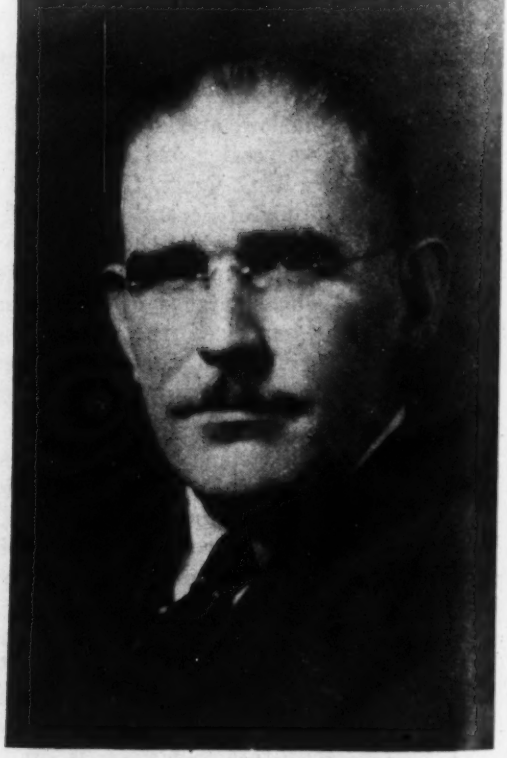
First Vice-President



G. L. Tuve
Cleveland, Ohio
Second Vice-President



John F. Collins, Jr.
Pittsburgh, Pa.
Treasurer

Systems, and the other on, Physiological Response of Subjects Exposed to High Effective Temperatures and Elevated Mean Radiant Temperatures.

M. S. Viteles, Ph.D., presented his paper on, An Experimental Investigation of the Effect of Change in Atmospheric Conditions and Noise Upon Performance, and G. V. Parmelee, Research Fellow at the Society's Research Laboratory, gave his paper on the subject, Shielding of Thermocouples from the Effect of Radiation.

At the conclusion of the technical papers W. T. Jones, Boston, Mass., past president of the Society, with the assistance of Messrs. M. F. Blankin, S. H. Downs, W. H. Driscoll and W. L. Fleisher, also past presidents, installed the newly elected officers as follows: President, Alfred J. Offner, Consulting Engineer, New York, N. Y.; First Vice-President, B. M. Woods, Dir., University Extension, University of California, Berkeley, Calif.; Second Vice-President, G. L. Tuve, Professor of Heat-Power Engrg., Case School of Applied Science, Cleveland, Ohio; Treasurer, John F. Collins, Jr., Pittsburgh, Pa., Secretary-Treasurer, National District Heating Association. The newly elected members of Council were installed as follows: Earl G. Carrier, Branch Mgr., Carrier Corp., Boston, Mass.; F. W. Hutchinson, Professor of Mechanical Engrg., Purdue University, Lafayette, Ind.; R. A. Sherman, Supvr., Fuels Div., Battelle Memorial Institute, Columbus, Ohio; and M. S. Wunderlich, Dir. of Research, Minnesota and Ontario Paper Co., Minneapolis, Minn.

A moment of silence was observed for the departed members, including a long list of those who had passed away during the year. Among them were, the former Director of the Research Laboratory, Commander F. C. Houghten, U.S.N.R., Past Presidents Thornton Lewis, Davis S. Boyden and C. B. J. Snyder, and former Treasurer of the Society, F. D. Mensing, and Mrs. Olive E. Frank, one of the first women members of the society.

A resolution of thanks was extended to the Committee on Arrangements of the New York Chapter, the Press, and others who had participated in making the Program a success.

At the opening luncheon R. H. Carpenter acted as toastmaster, and the speaker was Harvey Wiley Corbett, prominent New York architect, whose subject was, Are We Over Mechanizing Life? The attendance of 330 greatly enjoyed Mr. Corbett's discussion of the problems of constructing buildings, their equipment and the operation and control of the mechanical devices that are installed.

During the Annual Banquet, at which W. H. Driscoll served as toastmaster, the presentation of the F. Paul Anderson Medal was made by Dr. W. H. Carrier, Syracuse, N. Y., to Capt. A. E. Stacey, Jr., for his contributions to heating, ventilating and air conditioning W. L. Fleisher presented the Past President's Emblem of the Society to the retiring president, Dr. C.-E. A. Winslow, and Dr. Winslow presented the Past President's Memory Book on behalf of the Council to S. H. Downs, Kalamazoo, Mich., who was president of the Society in 1944. A special presentation by H. J. Ryan, president of New York Chapter, was made to Mr. Driscoll to commemorate the fact that he had served as president of the Society in 1926, as president of the New York Chapter in 1916, that his membership in the Society commenced in 1904, and also that 1946 marked the 50th year of his entry into the field of heating, ventilating and air conditioning.

**Times Square after Mardi-Gras Dinner**

The speaker of the evening was Leland Stowe, well known journalist, foreign correspondent and author, who talked on, What We May Expect in the Future, and particularly the problems of the atomic age.

(A complete report of the proceedings of the meeting will appear in the March issue.)

# Semi-Annual Meeting To Be Held in Montreal

**June 17-19, 1946**

# SUMMARY OF LOCAL CHAPTER MEETINGS*

CENTRAL OHIO—December 17, 1945. Subject: Housing Research, An Aid to the Heating and Ventilating Engineers. Speaker: Carl F. Boester, Housing Research Executive, Purdue Research Foundation, Purdue University, Lafayette, Ind. Mr. Boester's talk proved to be particularly fine and interesting, as reported by the secretary. Other features: R. R. Walker and A. I. Brown were elected as Chapter delegate and alternate; and H. R. Allonier and J. D. Slemmons were elected as representative and alternate on the nominating committee. Attendance, 48. Attendance ratio, 0.60.

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CINCINNATI—December 11, 1945. Subject: Magic in Electronics. Speaker: Gordon Volkenant. Mr. Volkenant's talk was enthusiastically received by the members and guests. Following a discussion, the speaker remained to answer questions as the members inspected the numerous gadgets and instruments which he used to illustrate his address. Other features: Five past-presidents of the Chapter were named to serve on the nominating committee with G. V. Sutfin as chairman. Messrs. Sproull and Mots were appointed to prepare resolutions expressing the Chapter's sympathies to the families of the late W. A. Evans and Amos L. Hard. Attendance, 36. Attendance ratio, 0.34.

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DELTA—December 5, 1945. Subject: Physiological Effects of Air Conditioning. Speaker: Dr. George Burch. The numerous comments and questions which followed Dr. Burch's talk indicated the interest in the subject. A rising vote of thanks was extended the speaker. Other features: The members and guests welcomed back Lt. Col. Frank G. Burns. Mr. Busenlener reported progress of the membership committee, and Mr. Cressy commented on meeting programs and attendance. Pres. W. H. Grant complimented the program committee for its work, and then requested Mr. Cressy to present a resolution to determine the Chapter's active part in political and civic affairs. Mr. Cressy requested the secretary to read a resolution prepared by the Exchange Club of New Orleans, concerning the labor problems at Higgins Industries. A motion was made and adopted that the Chapter go on record as endorsing the action of the Exchange Club. Attendance, 16. Attendance ratio, 0.26.

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GOLDEN GATE—December 12, 1945. Subject: Climatic Conditions as They Affect Design. Speaker: C. E. Norquest, Officer in Charge of the San Francisco Weather Bureau Office. Mr. Norquest presented the chapter members with a copy of the November issue of the monthly *Meteorological Summary;* the *Annual Meteorological Summary for* 1944, and the *Agricultural Year Book,* summarizing climatic conditions throughout the State of California. During the discussion period, Mr. Norquest stated that wind velocity should have no effect on design, since usually the wind is the same temperature as still air. It seems cooler only because it picks up surface heat and also surface moisture from the body and carries it away. He further stated that minimum temperatures usually occur under clear skies and in still air. John Kooistra suggested that the psychrometric data in the monthly bulletin be incorporated in the annual bulletin when it is again published. John Everetts, Jr., told that back in 1933 the Weather Bureau started to take more readings, and since 1937 has had records from many stations on wind velocities, wet-bulb temperatures, etc. These data are now available in tabulated form from more than 350 cities in the United States. Attendance, 47. Attendance ratio, 0.58.

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ILLINOIS—December 10, 1945. Subject: Panel Discussion on Temperature Control. Members of panel: Harold Alyea, Johnson Service Co.; J. E. Haines, Minneapolis-Honeywell Regulator Co.; A. J. Keating, Powers Regulator Co.; and Victor Lathers, Barber-Colman Co. Each of the speakers illustrated his talk with slides or blackboard diagrams. Other features: E. B. Ericsson, the Chapter's delegate to the Chicago Technical Societies Council, reported that an extensive amendment to the CTSC by-laws was up for vote. On motion from the floor, it was referred to the board of governors for whatever action deemed necessary. Attendance 134. Attendance ratio, 0.77.

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INDIANA—January 4, 1946. Subject: Electronic Air Cleaning, Theory and Practice. Speaker: James W. May, Dir. of Research, American Air Filter Co., Louisville, Ky. Other features: Mr. Ammerman reported on the activities of the membership committee. L. W. Clark submitted the treasurer's report. Attendance, 42. Attendance ratio, 0.51.

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KANSAS CITY—January 7, 1946. Subject: Dehumidifying Air with Coils. Speaker: William Goodman, Illinois Institute of Technology. Professor Goodman illustrated his talk with slides, and a question-and-answer period followed. Other features: The proposed amendment to the Society's Constitution was discussed, and President Mason announced that the subject was previously discussed by the officers and board of directors of the Kansas City Chapter. After considerable discussion, a motion was made and unanimously carried, that the Chapter is opposed to that feature of the proposed

* Note. The attendance ratios shown above represent the meeting attendance divided by the chapter membership. These ratios will be useful as a partial indication of interest shown by local chapter members in various types of subjects programmed by the various chapters and may be useful in deciding on subjects for chapter meetings.

amendment to Article B-VIII, Section 11, whereby the Council appoints four of the eleven members of the nominating committee and, therefore instructs its representatives to vote against this proposed amendment. Attendance, 60.

KANSAS CITY—December 13, 1945. Subject: Temperature Effect on the Human Race. Speaker: Dr. Clarence Mills, University of Cincinnati. This was a joint meeting with the ASRE, and was held in the Pine Room of Union Station. Attendance, 49.

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MASSACHUSETTS—December 18, 1945. Subject: The Use of Copper Tubing in Radiant Heating Installations. Speaker: K. C. Woodward, Chase Brass and Copper Co., Inc. Pres. D. M. Archer presided at this meeting which was held in the Club Room of Thompson's Spa, Boston.

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MEMPHIS—December 10, 1945. Vice-Pres. R. H. Hoshall presided in absence of Pres. T. J. O'Brien. After dinner a film was presented entitled, There is an Engineering Reason, through the courtesy of Yarnall-Waring Co., Philadelphia, Pa. Messrs. Cox and Rhodes, local representatives of the firm, were in attendance to answer questions. W. E. Thorpe, chairman of the meetings committee, announced that Orion O. Oaks, John B. Pierce Foundation, Raritan, N. J., will be the speaker at an early meeting of the chapter. Announcement was also made of the proposed departure to Atlanta, Ga., of F. H. Bigelow, and the chapter's regrets were expressed. Herbert Wilson will succeed him as district manager for Ilg Electric Ventilating Co., as announced at the meeting. Attendance, 16. Attendance ratio, 0.59.

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MICHIGAN—December 17, 1945. Subject: Gas Yesterday, Today and Tomorrow. Speaker: Hugh J. Sheean. Movies of the installation of the gas line serving Detroit were shown and the talk proved interesting and instructive. The speaker answered numerous questions, and a rising vote of thanks was extended him. Other features: R. K. Milward read a card received from Tom Brown, and the president thereupon appointed a committee, with Mr. Milward as chairman, to send Christmas greetings to Tom Brown in the form of something good to eat. Messrs. H. E. Paets and A. E. Knibb were named to assist Mr. Milward. E. F. Hyde reported as treasurer. M. B. Shea reported on the progress of the membership committee. Attendance, 62. Attendance ratio, 0.49.

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MINNESOTA—December 3, 1945. Subject: The Story of Atomic Energy. Speaker: Dr. J. W. Buchta, chairman of the Physics Department, University of Minnesota, Minneapolis, Minn. Dr. Buchta stressed the developments that led to the manufacture of the atomic bomb. His talk was illustrated by slides and a number of demonstrations were made with radio-active materials. Other features: John E. Haines and Bruce McLouth were elected to serve as Chapter delegate and alternate to the 52nd Annual Meeting in New York. F. W. Legler was elected to serve as Chapter representative on the nominating committee at the Annual Meeting. R. E. Backstrom reported as chapter representative to the Minnesota Federation of Architects and Engineers Societies. Attendance, 70.

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MONTREAL—December 29, 1945. Election of officers: President, A. B. Madden; Vice-Pres., T. H. Worthington; Secretary, S. W. Salter; Treasurer, C. A. Booth. Board of Governors: J. H. Chenevert, Leo Garneau, Ralph Grossman, F. G. Phipps, and W. W. Timmins. Attendance, 43. Attendance ratio, 0.45.

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NEBRASKA—December 13, 1945. Subject: Performance of Radiant Baseboard in the I=B=R Research Home. Speaker: Prof. W. S. Harris, Engineering Experiment Station, University of Illinois, Urbana, Ill. Professor Harris' talk was well received. He showed slides and charts demonstrating the comfort conditions produced with this type of radiator. The discussion following his talk indicated the great deal of interest in the subject. Attendance, 24.

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NORTH CAROLINA—August 4-5, 1945. The summer meeting of the chapter was held at Sedgefield Inn, with members, wives and guests in attendance. A golf match was scheduled for Saturday afternoon and Sunday morning, with bridge for the ladies. Saturday evening dinner was served in the grill and Prof. R. B. Rice presided as toastmaster. He introduced Dr. H. G. Baity, who gave an interesting talk illustrated by Kodachrome slides. His subject was *A Leica Looks at Brazil.*

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NORTHERN OHIO—December 10, 1945. Subject: Community Smoke Elimination Problems. Speaker: Raymond R. Tucker. He gave the history of the efforts in eliminating smoke problems in St. Louis and stated that success in such a program can only be obtained with the full support of all citizens, the press, radio, business, etc. Other features: John James and J. E. Wilhelm were elected as chapter delegate and alternate to the Annual Meeting, while D. L. Taze and R. L. Byers were unanimously elected as representative and alternate to serve on the nominating committee. Future programs were announced, giving the speaker and subject of discussion for the first five meetings of the season. Philip Cohen introduced Mr. Allen of the City of Cleveland, who read a paper written by A. E. Hutchinson, Smoke Commissioner, Cleveland, on *Cleveland Smoke Abatement Program.* Dr. George Sanford, Professor at Case School of Applied Science, and speaker from the Council on World Affairs, gave an interesting talk on Three Implications of Revolutions in South America. Attendance, 130. Attendance ratio, 0.90.

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OKLAHOMA—December 4, 1945. Subject: Fans, Their Design and Application. Speaker: T. H. Anspacher, Dist. Mgr., Buffalo Forge Co., Dallas, Tex. Mr. Anspacher's

talk was well delivered and equally well received. An active interest was shown in the subject, resulting in considerable discussion on fan problems. Attendance, 24. Attendance ratio, 0.72.

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ONTARIO—January 7, 1946. Subject: Society Research—Its Past, Present and Future. Speaker: Cyril Tasker, Director of Research, ASHVE Research Laboratory, Cleveland, Ohio. V. J. Jenkinson reported *On to New York* for the 52nd Annual Meeting of the Society. Attendance, 87. Attendance ratio, 0.48.

ONTARIO—December 3, 1945. Subject: A Short to Understanding. Speakers: T. J. Abbott, Secy-Treas., George C. Abbott, Ltd., T. H. McLaren, Gen. Sales Mgr., The James Morrison Brass Mfg. Co., Ltd., F. Ewart, Ewart, Armer and Byam, and O. L. Robb, Empire Brass Mfg. Co., Ltd. H. R. Roth announced that the Ontario Chapter's representative on the Nominating Committee for the coming season is V. J. Jenkinson, with D. A. Stott as alternate. Mr. Jenkinson will also act as the chapter's delegate, and E. G. Spall as his alternate. Attendance, 102. Attendance ratio, 0.46.

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OREGON—December 6, 1945. Subject: Functions of the United States Patent Office. Speaker: E. A. Buckhorn, U. S. Patent Office. Mr. Buckhorn illustrated his lecture and covered many unusual patents. Motion was made and carried to forego having the Air Conditioning Conference this year because of the lack of time for proper preparation. Attendance, 29.

OREGON—November 9. Subject: The Engineer in the Post War World. Speaker: Dr. C.-E. A. Winslow, President of ASHVE and Dir., John B. Pierce Laboratory of Hygiene, New Haven, Conn. Dr. Winslow's talk was well received and thoroughly enjoyed by the members. A vote of appreciation was extended to Dr. Winslow for his fine presentation. Attendance, 40.

OREGON—October 8. Subject: Housing Research—An Aid to the Heating and Ventilating Engineer. Speaker: C. F. Boester, Housing Research Executive, Purdue Research Foundation, Purdue University, Lafayette, Ind. Mr. Boester also stressed the importance of properly instructing the chapter delegates on voting at Society Meetings. Attendance, 31.

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PHILADELPHIA—December 13, 1945. An open forum was held on the subject of Air Conditioning and Equipment for Homes. A great deal of interest was shown by the members present and all took part in the various phases of the problem. Attendance, 47.

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PITTSBURGH—December 10, 1945. Subject: Axial Flow Fans. Speaker: W. R. Heath, Chief Engr., Fan Division, Buffalo Forge Co., Buffalo, N. Y. Mr. Heath spoke about the development of the fans, which came originally from the Russians and later from the English, and also about the different types of fans and what the axial fan is to do in the field of ventilation. Mr. Heath showed slides to demonstrate some of its uses in this field. An interesting discussion followed, with many questions answered by the speaker. Attendance, 30. Attendance ratio, 0.42.

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ROCKY MOUNTAIN—December 5, 1945. Subject: Water Cooling Equipment, Cooling Towers and Spray Nozzles. Speaker: L. T. Mart, President, The Marley Co., Inc. The speaker pointed out that the function of water cooling equipment was to dissipate heat from engines, oil refineries, air conditioning equipment and many other sources. He mentioned the different requirement in each case and that water treatment was important to cooling tower life. He also discussed the different methods of cooling, such as spray ponds, natural draft, forced draft and induced draft towers, the advantages and disadvantages of each method. His talk was well illustrated with slides showing old and new methods and cooling towers from all over the world. Considerable discussion followed. Other features: Pres. G. D. Maves announced that Fred Janssen would be the Chapter delegate and serve on the nominating committee and L. M. Hook would be the alternate, to attend the Annual Meeting in New York. An amendment to the Chapter by-laws and rules was duly submitted and approved. Attendance, 46. Attendance ratio, 0.71.

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ST. LOUIS—December 7, 1945. Subject: Scientific Information on the Atomic Bomb Released by War Department. Speaker: Dr. Frank W. Bubb, Mathematical Department, Washington University. The speaker explained that the technical information, or *know how to use* was still a secret for reasons of national security. He described the devastating power of the atomic bomb in great detail, and its almost supernatural destructiveness pictured as a force which could well destroy civilization if allowed to fall into improper hands and be used ruthlessly by aggressive world conquerors. The potential danger of the use of atomic bombs by enemy agents as saboteurs was pointed out, and also the danger, if any of our enemies should learn or be advised of the secret of the mechanical details of using atomic bombs. He stated that Great Britain, Canada and the United States had worked together in the development of the atomic bomb, and that our English allies had shown a remarkable amount of confidence in us, turning all of their information over to us without any particular assurance that the atomic bomb might not be used as a weapon against them. A lengthy and interesting discussion followed Dr. Bubb's talk, after which Pres. W. J. Oonk thanked the speaker on behalf of the St. Louis Chapter for this very interesting talk. Other features: President Oonk was elected as the Chapter delegate to the Annual Meeting in New York, with W. A. Russell as his alternate; Mr. Russell was also elected to serve as the representative on the nominating committee, with President Oonk as the alternate. Attendance, 32.

SOUTH TEXAS—December 14, 1945. Dale Cooper, chairman of the code committee, made a report advising that the committee hoped to hold an informative school on heating and ventilating for the Chapter. R. B. Johnson was nominated and unanimously elected to succeed R. F. Taylor as a member of the Engineers Council of Houston, for a two-year period. A. F. Barnes, whose term expired at the end of this year, was asked to serve for another year on the Council. Charles Quin was nominated as alternate for the Engineers Council. D. M. Mills was appointed as representative on the nominating committee to attend the Annual Meeting in New York, with J. A. Walsh as alternate. W. J. Way was chairman for the evening and acted as Santa Claus, and distributed presents to all the members, and a lively time was had while the wrappings were being removed and the contents examined. Attendance, 39.

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SOUTHERN CALIFORNIA—December 12, 1945. Subject: Refrigeration of Tuna Clippers. Speaker: Ralph Manns. The speaker explained that the principle of the refrigeration system is merely to conserve ice for the extent of the fishing trip. Some very interesting highlights were disclosed regarding the refrigeration systems, as well as the art of tuna fishing. For example, where the water is below 68 F no tuna are in evidence, hence most of this fishing is done off the coast of lower California and down as far as Costa Rica. The intense bombings in the Pacific area have driven the tuna over to this side and they are more plentiful now than before the war. The speaker brought out an interesting fact, that 15 to 20 ton of fish can be caught in 15 min. by 16 fishermen. It was also pointed out that tuna can be carried 14 to 21 days at 30 deg to 35 deg; 30 to 40 days at 10 deg and below 10 deg they have been kept satisfactorily up to 120 days. Mr. Manns stressed the necessity of keeping the system simple so that the fishermen or boat engineer could operate it, stating that it was better to sacrifice efficiency for simplicity. At the conclusion of his talk, two reels of tuna fishing expedition pictures were shown. Other features: Art Theobald was chosen as delegate, and R. A. Lowe was selected as alternate, to attend the Society's 52nd Annual Meeting in New York. Attendance, 65.

SOUTHERN CALIFORNIA—November 14, 1945. Subject: The Air Cooled Human Body. Speaker: Dr. C.-E. A. Winslow, Pres. of ASHVE, and Dir., John B. Pierce Laboratory of Hygiene, New Haven, Conn. Dr. Winslow provided the Chapter with an extremely entertaining evening. He reminded the members that the Annual Meeting of the Society is scheduled for New York, January 28-30, 1946. Attendance, 60.

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UTAH—December 15, 1945. D. R. Wilde reported on the manner in which the nominating committee selected the candidates for officers for 1946-47. It was approved by those present that the candidates for office be voted on by the chapter membership by means of mailed ballots to be sent out by the secretary. J. T. Young, Jr., was nominated and elected as delegate, and D. R. Wilde was elected as alternate to the Annual Meeting in New York. Pres. H. G. Richardson called for comments on the type of meetings preferred, and this was discussed in detail. Following the business meeting, J. T. Young, Jr., showed two sound films, one on *Life Lines of Industry* and the other on *Realm of the Wild*. Both films proved interesting. Attendance, 13. Attendance ratio, 0.42.

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WASHINGTON, D. C.—December 12, 1945. Subject: Liquid Heat. Speaker: Orion O. Oaks, Chief Engr., John B. Pierce Foundation, Raritan, N. J. Mr. Oaks stated that the Foundation is sponsoring an investigation to discover a technique for providing all the heat services of buildings from one source. This involved a search for an ideal working substance which would have advantages over air, water and steam. A lively question and answer period followed. Other features: Pres. W. H. Littleford opened the meeting by welcoming the members of the Washington Association of Heating, Piping and Air Conditioning Contractors, which sponsored the joint meeting with the Washington Chapter of the Society. Brig.-Gen. W. A. Danielson, Memphis, Tenn., the first president of the Chapter, and Capt. T. H. Urdahl, each spoke briefly and emphasized the brightness and opportunity of the Society's future. The president then announced the resignation of Secretary Lester Maurer, and F. B. Sale, a member of the board of governors, both of whom are leaving to accept employment in Norfolk, Va., and New York, respectively. President Littleford extended them the Chapter's good wishes and then appointed a nominating committee to submit nominations to fill the vacancies at the next meeting. The committee appointed consisted of: Glegge Thomas, chairman; G. R. Walz, and A. S. Gates, Jr. Attendance, 43.

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WESTERN MICHIGAN—December 3, 1945. Subject: Hazards Present in Air of Many Industrial Plants. Speaker: W. C. Hemeon, Ventilation Engr., Industrial Hygiene Foundation of America, Inc., Pittsburgh, Pa. The speaker emphasized the necessity of collecting the harmful dusts and gases at their source if possible. Other features: John C. Soet, Engineer of the Michigan State Health Department, spoke about the instruments that were used for sampling air to determine amounts of harmful dust and gas present in these samples. Several testing instruments were set up and those present were invited to examine them closely. Attendance, 57. Attendance ratio, 0.91.

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WISCONSIN—November 19, 1945. Subject: Welding as Applied to Pipe Fabrication and Installation. Speaker: Fred Fantz, Vice-President in charge of engineering, Midwest Piping and Supply Co., St. Louis, Mo. Mr. Fantz gave a brief outline of the development of fusion and resistance welding. An interesting discussion followed, and a rising vote of thanks was extended the speaker. Other features: H. K. Pride announced that William A. Ouweneel, former member of chapter, had returned to Milwaukee and rejoined the Wisconsin Chapter. Mr. Ouweneel received a hearty welcome from the members. Attendance, 46. Attendance ratio, 0.58.

# Committee on Research
## Three-Year Term

**L. N. Hunter, Johnstown, Pa.**—Vice-President, and Manager of Research, National Radiator Corp., was born at Brampton, Ontario, Canada, August 27, 1903, where he received his preliminary education. He received his degree of B.A.Sc. in 1925 from University of Toronto.

His first assignment was with the Bryant Heater Co., Cleveland, Ohio, as assistant research engineer. After four years he joined the staff of the National Radiator Corp., Johnstown, Pa., as gas engineer. His duties included designing and testing gas-fired house heating boilers and adapting controls; he also designed and tested special cast-iron gas-fired boilers for treating crude oil emulsions. In 1932 he was made assistant manager of the Research Department, where he supervised the designing, testing and

L. N. Hunter
Johnstown, Pa.

research work on coal, oil and gas-fired boilers, oil burners, stokers, radiators, convectors and air conditioning equipment, and accessories and controls. He became manager of the Research Department in February 1935, and in 1941 was appointed vice-president and manager of research.

Mr. Hunter joined the Society in 1935 and has served on several Technical Advisory Committees on Radiation and Comfort, and on the Solid Fuels Committee from 1939 to 1942.

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**C. O. Mackey, Ithaca, N. Y.**—Professor of Heat Power Engineering at Cornell University, was born in Ithaca in 1903. He received his M.E. in 1926 from Cornell, and in 1927 he became an instructor in experimental engineering at the University. He later became instructor in heat-power engineering, and in 1929 was appointed Assistant Professor in heat-power engineering, and in 1936 became Professor.

Professor Mackey is in charge of the Mechanical Engineering Laboratory at the University.

He has presented several papers before Society meetings, having joined the Society in 1943. Professor Mackey is also a member of the

C. O. Mackey
Ithaca, N. Y.

*American Society of Refrigerating Engineers* and the *Society for the Promotion of Engineering Education.*

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**R. D. Madison, Buffalo, N. Y.**—Research Engineer, Buffalo Forge Co., was born in Terre Haute, Ind., April 28, 1891. He attended Rose Polytechnic Institute, Terre Haute, receiving his B.S. in mechanical engineering in 1913.

Mr. Madison received his early training with the Hydraulic Press-Brick Co., Brazil, Ind., followed by a year's experience with Crawford and McCrimmon Co., both in Brazil, Ind. He also spent a year with William, Seaver Morgan Co., Cleveland, Ohio, before joining the staff of the U. S. Army Ordnance Department, Washington, D. C. During his four years association with the Army Ordnance he was stationed at Sandy Hook, Peoria, Dayton, and Indianapolis.

In 1919 he first joined the staff of the Buffalo Forge Co., where he soon became Research Engineer.

He joined the Society in 1925, and has been closely connected with its research work since that time.

R. D. Madison
Buffalo, N. Y.

He has served for many years as a member of the Technical Advisory Committee on Air Distribution and Air Friction, as well as a member of the Technical Advisory Committee on Sound Control since 1941, and as its Chairman in 1945. Mr. Madison is a familiar figure at Society Meetings.

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**L. P. Saunders, Lockport, N. Y.**—Chief Engineer of Research Engineering, Harrison Radiator Div., General Motors Corp., was born at Stroud Green, London, England, June 24, 1891. He received his elementary training from private tutors in both England and the United States, and attended Westbourne Grove College, England.

His first business connection was with Messrs. Legros and Knowles, London, automobile manufacturers, and from 1910 to 1914 he was associated with various U. S. and Canadian factories.

During World War I he served in the British Navy as an engineer on diesel engine craft, and following the war he joined General Motors Research Corp., Dayton, Ohio. In 1920 he joined the staff of the Harrison Radiator Division of the

**L. P. Saunders**
**Lockport, N. Y.**

Corporation, where he developed modern methods of car radiator testing in the laboratory.

Mr. Saunders joined the Society in 1933, taking an active part in the activities of the Western New York Chapter. He served as its treasurer, 2nd vice-president, 1st vice-president, and president during the period from 1936 to 1939. He also served on many of its local committees and as a member of several of the Society's Research Technical Advisory Committees.

He was elected a member of the Society's Council in 1941 and in 1943 he was elected to serve a three-year term as a member of the Committee on Research. Mr. Saunders has also served on such committees as the Chapter Relations, as chairman of the Standards, the Technical Advisory Committees on Corrosion, the Flow of Fluids Through Pipes and Fittings, Heat Transfer of Finned Tubes, and Air Distribution and Air Friction.

Mr. Saunders has written extensively on evaporative cooling, and radiator development and car cooling for *Society of Automotive Engineers Journal*, and on research and automotive progress for other publications. He holds membership in numerous engineering societies and clubs.

## C. A. DUNHAM RETIRES

C. A. Dunham, founder of the C. A. Dunham Co., Chicago, Ill., and President since its organization, relinquished the Presidency on December 31, 1945, for reasons of ill health. He was succeeded by H. S. Marshall, for many years counsel and later Vice-President. Associated with him are C. W. Neill, 1st Vice-President; F. E. Schmidt, 2nd Vice-President. C. M. Brigham, 3rd Vice-President; A. R. Welker, Secretary and Treasurer. On the same date Mr. Dunham was elected Chairman of the Board with the duty of advising as requested by the Board.

In 1903 the first commercial Dunham traps were made in a small basement shop in Marshalltown, Ia. The following year the first Dunham factory came into existence with the purchase of a wooden structure opposite the site of the present modern plant, which was built in 1910, enlarged in 1913, 1917, and again in 1925.

A steady expansion marked the 20 years which followed. The Young Pump Co., the Prier Brass Foundry, the Dwyer Equipment Co. were acquired. A modern plant was built in Michigan City. Sales offices were established in Canada and in London, England. C. A. Dunham Co., Ltd., was organized in Canada and also in England. Modern office buildings and factories were built in Toronto and London.

The Dunham differential vacuum heating system, developed in the company's research Laboratories, was announced in 1927, and since that time installations are to be found in all parts of the world.

Mr. Dunham joined the Society in 1911 and now holds Life Membership. He is a familiar figure in the heating and ventilating field, having presented numerous papers before Society meetings from time to time.

## H. J. PREBENSEN RETURNS TO INACTIVE SERVICE

H. J. Prebensen has rejoined Air Comfort Corp., Chicago, Ill., manufacturers and distributors of commercial and industrial air conditioning and refrigeration equipment, as executive vice-president and director, according to an announcement by H. E. Wheeler, president.

Colonel Prebensen was one of the original organizers of the company in 1935 and served as a director and vice-president in charge of engineering until he left to enter military service in February 1942.

During the war he was assigned to the Chicago Ordnance District, where he was successively assistant chief of the tank-automotive branch, chief of the production service branch, and chief of the industrial division. In this last position, which he held from June 1944 until his release from active duty in December 1945, he supervised the activities of the District's tank-automotive, ammunition, artillery, small arms, inspection, and production service branches. Production of ordnance material by district contractors while Colonel Prebensen was chief of the industrial division approximated $2,000,000,000.

In his new capacity as executive vice-president of Air Comfort, Colonel Prebensen will be in charge of the company's engineering, manufacturing, and contracting operations. He is a graduate of the Illinois Institute of Technology, holding degrees in both mechanical and electrical engineering. He joined the Society in 1938 and has taken an active interest in the affairs of the Illinois Chapter.

## ARTHUR McGONAGLE DIES IN PITTSBURGH

Arthur McGonagle, a native of Norristown, Pa., died at his home, 6815 Prospect Ave., Ben Avon, Pa., on January 6, 1946, after a short illness. Mr. McGonagle was born in Norristown, July 29, 1867, where he received his early education.

Mr. McGonagle, a resident of Pittsburgh since 1912, has been in the heating and ventilating business for more than fifty years. He designed the heating and ventilating systems for many of Pittsburgh's leading buildings, including the Mellon Institute, William Penn Hotel, City-County Building, the Liberty Vehicular Tunnel, and other projects.

He joined the Society in 1932 and took great pride in his membership.

**Arthur McGonagle**
**Pittsburgh, Pa.**

He was active in the Pittsburgh Chapter, having served as a member of its Board of Governors in 1937. He was a member of the Ben Avon Presbyterian Church.

Mr. McGonagle is survived by a son, F. Robert McGonagle, Chicago; two daughters, Sarah H. McGonagle, Albany, N. Y., and Mrs. Frances Weigand, Pittsburgh, Pa., to whom the Officers and Council of the Society extend their heartfelt sympathy.

## F. D. MENSING, FORMER TREASURER, DIES

Frederick D. Mensing, well known consulting engineer of Philadelphia, Pa., died on December 27, 1945, according to word received recently. Mr. Mensing was born in Philadelphia, June 2, 1879, attended public schools there, and was privately tutored.

His first assignment in the business world was in 1898 when he worked as draftsman on plant and apparatus drawings for the Gruson Iron Co., Philadelphia. A year later he joined the staff of the engineering department of the Bell Telephone Co., and in 1900 he was appointed assistant chief draftsman, supervising and designing apparatus, conduit and pole lines. Later he was transferred to the Line Department, where he worked on line surveying, design and general aerial construction engineering. He resigned in 1905 to take up an assignment with the Kinetic Engineering Co., Philadelphia, where he designed calculating machines.

In 1906 he became associated with the Jacob Myer and Sons, contractors and builders, where he worked as assistant to the superintendent of construction on the Jefferson Hospital. He was in complete charge of the electrical, mechanical and sanitary plant installation and the layout of apparatus for this building.

From 1907 to 1913 he was associate engineer for Isaac Hathaway Francis, Jr., consulting engineer, Philadelphia. During this time Mr. Mensing supervised the design and installation of the mechanical, electrical, and sanitary plants for the Lafayette Building, Girard Estate Power House, Girard College Power Plant, Denkla Building, Riggs Building and Theatre, Washington, D. C., West Chester State Normal School, West Chester, Pa., Johnstown, Y.M.C.A., Sage Dormitories, Princeton University, Princeton, N. J., etc.

In 1914, Mr. Mensing was retained by Ballinger and Perrot to organize and to have complete charge of department, to handle all equipment of buildings designed by them. During the three years that followed, Mr. Mensing designed and supervised the mechanical, electrical, and sanitary equipment in well over 50 buildings in Philadelphia, New York, Pennsylvania and New Jersey.

F. D. Mensing
Philadelphia, Pa.

In February 1917 he opened his own office as consulting engineer in Philadelphia, where he handled such jobs as Union Mills Paper Mfg. Co., New Hope, Pa., Floyd-Wells Co., Royersford, Pa., the A. M. Collins Mfg. Co., Philadelphia, Universal Paper Bag Co., New Hope, Pa., Elkins Memorial Home, Philadelphia, West Jersey Homeopathic Hospital, Camden, N. J., Cornell University (Boldt Hall) Ithaca, N. Y., Fraternity House, Delaware College, Newark, Del., Collingswood High School, Collingswood, N. J., and numerous others.

During World War I, Mr. Mensing was in charge of the installation of all steam pipe, etc., for the Ordnance Department of the Perryville, Md., Nitrate Plant.

Mr. Mensing also acted as consultant relative to ventilation of Executive Committee rooms for E. I. DuPont DeNemours, Wilmington, Del.

Mr. Mensing joined the ASHVE in 1920, and took an active interest in both the affairs of the Society and the local Philadelphia Chapter, of which he was a member. He served as President of the Philadelphia Chapter in 1922, as a member of its Board of Governors in 1923, and was elected Treasurer of the Society in 1931 and 1932. He also served on many special committees of the Society and in 1924 was chairman of the Guide Publication Committee. He also served as a member of the Committee on Research.

The Officers and Council of the Society extend their sincere sympathy to his family who survives.

## MRS. OLIVE E. FRANK'S DEATH ANNOUNCED

Members attending the Society's recent Annual Meeting in New York were shocked when the death of Mrs. Olive E. Frank was announced on January 28, 1946. Mrs. Frank, one of the first women to join the Society, died in a private nursing home in Paterson, N. J. Her home was in suburban Pines Lake, where she lived on Algonquin Trail.

Mrs. Frank, only 56, for the past twenty years had designed heating and ventilating devices and supervised their construction as president and treasurer of her own company, the Frank Heaters Co., Inc., which she organized in Buffalo, later moving to New York City. Six years ago she moved the company offices and plant to Paterson.

She was born in Buffalo, in August 1889, where she attended school. She began her unusual career in Buffalo where she was employed as a stenographer for plants manufacturing heating equipment. She soon tired of this work, and decided to enter the engineering field. She taught herself, sitting up nights studying models of condensers and cooling tanks. Learning the techniques of drafting, she then became a traveling saleswoman for the Howard Iron

Mrs. Olive E. Frank
Paterson, N. J.

Works, and its associate concern, the Alberger Heater Co., both of Buffalo. Mrs. Frank was in complete charge of the mechanical engineering, including the designing and estimating of all problems pertaining to heaters and coolers, which embraced feed water heaters, forced circulation heating systems, etc.

In 1930, with her husband, Harry S. Frank, who died six years ago, Mrs. Frank founded Frank Heaters, Inc., Paterson, N. J. Previously she had formed and managed the O. E. Frank Heater and Engineering Co., Buffalo.

In 1919 Mrs. Frank joined the Society, taking an active part in its activities, as well as its Chapter activities in Buffalo and New York.

In 1943 she was elected president of the Paterson Zonta Club, a professional and business women's organization, which she helped to organize. Mrs. Frank was also a member of the *American Society of Mechanical Engineers*, as well as a member of the Eastern Star, Chapter 386 of Buffalo.

She is survived by a sister, Mrs. Ruth Lillian Naursich, Buffalo, and three brothers, Chauncey J. Cook and Irving W. Cook, Buffalo, and James Kermit Cook, River Trail, Pines Lake, N. J., to whom the Officers and Council of the Society extend their sincerest sympathy for the loss they have sustained.

# Candidates for Membership

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 62 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by March 15, 1946, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

ALLEN, R. H., Owner, Allen Copper Coil Co. PROPOSERS: D. C. Griffin, J. H. Faulkner. SECONDERS: E. H. Langdon, M. N. Musgrave.

BAKER, RUSSELL A., Branch Mgr., Minneapolis-Honeywell Regulator Co. PROPOSERS: I. W. Gilbert, L. E. LaRow. SECONDERS: C. F. Woese, Merle Weninger.

BECHIR, NICHOLAS V., Asst., Refrig. Dept., Volkart Brothers. PROPOSERS: F. J. Rider, J. M. Rachal. SECONDERS: E. W. Kutil, C. M. Stuart.

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BOVAY, HARRY E., JR., Cons. Engr. PROPOSERS: Alfred Natkin, F. C. Brandt. SECONDERS: W. C. Timmermann, A. F. Barnes.

BRINEN, HOWARD F., Research Engr., Young Radiator Co. PROPOSERS: F. H. E. Weil, R. L. Johnson, SECONDERS: E. F. Higgins, G. J. Haislmaier.

BRYDIA, ELLIS M., Equip. Dvlpt. Engr., York Corp. PROPOSERS: E. R. Walsh, Jr., L. J. Du Bois. SECONDERS: L. S. Morse, Sr.*, W. E. Zieber.

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DAVIS, WILSON L., Sales Engr., American Blower Corp. PROPOSERS: G. B. Supple, T. R. Davis. SECONDERS: G. O. Jackson, I. W. Cotton.

DOUGHERTY, CHARLES P., Owner, Dougherty Heating Co. PROPOSERS: A. E. Finlay, J. J. Byrne. SECONDERS: S. S. Day, A. C. Clark.

EDELMAN, HERBERT W., Mgr., Purchasing Dept., Baker Manufacturing Co. PROPOSERS: B. G. Peterson, J. C. Engskow. SECONDERS: K. R. Magarrell, D. E. McCulley.

ELLIS, MILTON H., JR., Sales Engr., Armstrong Cork Co. PROPOSERS: F. H. Bigelow, W. E. Thorpe. SECONDERS: J. J. Nolan, Oliver Holmes.

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FAIRCLOUGH, ROY J., Mgr., Htg. Dept., Crane Co. PROPOSERS: J. T. Young, Jr., H. G. Richardson. SECONDERS: W. H. Sayler, E. V. Gritton.

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FITZSIMONS, ROBERT H., Dist. Mgr., Trane Co. PROPOSERS: J. P. Fitzsimons, A. M. Dion. SECONDERS: D. A. Long, William Philip.

FRANKLE, MILTON S., Partner, Air Control, Inc. PROPOSERS: H. R. Frankle, D. E. Wells. SECONDERS: F. E. Triggs, T. R. Johnson.

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SHUSTER, WILBUR W., Cons. Engr., Bodenstein & Shuster. PROPOSERS: R. W. Sigmund, M. E. Mathewson. SECONDERS: G. B. Houliston, H. K. Jennings.

SMITH, HARLEY H., Mgr., Govt. Dept., United States Radiator Corp. PROPOSERS: R. H. Feltwell, R. S. Dill. SECONDERS: J. F. McIntire, G. T. Underwood.

STEPHENSON, JAMES H., Sales Engr., Johnson Service Co. PROPOSERS: J. A. Walsh, F. C. McIntosh. SECONDERS: M. A. Benson, R. F. Taylor.

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WOLLRIK, HELGE V., Head of Htg. & Vent. Dept., A. B. Gustavsbergs Fabriker. PROPOSERS: F. J. Kluempers*, James Blare*. SECONDERS: Einar Kumm*, H. T. Marks*.

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*Non-Member

# Candidates Elected

In the past issues of the Journal of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Committee on Admission and Advancement and ballotted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. B-III, Sec. 8, of the By-Laws, the following list of candidates elected:

## Members

HAMILTON, M. S., Southeastern Sales Mgr., Air Cond. Controls Div., Minneapolis-Honeywell Regulator Co., Atlanta, Ga. *(Reinstatement)*

SAUNDERS, CLAUDE V., Mech. Engr., Louis C. Kingscott & Associates, Kalamazoo, Mich. *(Reinstatement)*

## Associates

BOEDDENER, GEORGE, Managing Dir., National Warm Air Heating & Air Conditioning Association, Cleveland, Ohio. *(Reinstatement)*

COOPER, W. B., N. Wilbraham, Mass. *(Reinstatement)*

PIERCE, EDGAR D., Sales Engr., Harold E. Peterson, Los Angeles, Calif. *(Reinstatement)*

SCHICK, KARL W., Sales Mgr., Minneapolis-Honeywell Regulator Co., Chicago, Ill. *(Reinstatement)*

## Junior

WEID, HARRY L., Philadelphia Electrical & Manufacturing Co., Philadelphia, Pa. *(Reinstatement)*

# American Society of Heating and Ventilating Engineers

Headquarters: 51 Madison Ave., New York 10, N. Y. (Tel.: AShland 4-0291)

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*Guide Publication:* T. F. Rockwell, *Chairman;* R. C. Cross, R. S. Dill, C. F. Kayan, B. H. Jennings, A. B. Newton, G. H. Tuttle, W. M. Wallace, II, C. P. Yaglou, Cyril Tasker, *Ex-Officio.*

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*Research Fund Raising:* A. C. Willard, *Chairman;* W. L. Fleisher, E. Holt Gurney, E. N. McDonnell, J. H. Walker, B. M. Woods.

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**Connecticut:** Organized, 1940. Headquarters, New Haven, Conn. President, Stanley Hart, New Britain. Secretary, Winfield Roeder, 405 Temple St., New Haven.

**Delta:** Organized, 1939. Headquarters, New Orleans, La. Meets Second Tuesday. President, W. H. Grant, Jr., 209 Vincent Bldg., New Orleans 12. Secretary, J. S. Burke, 317 Baronne St., New Orleans 9.

**Golden Gate:** Organized, 1937. Headquarters, San Francisco, Calif. Meets, First Wednesday. President, R. B. Holland, 420 Market St., San Francisco 11. Secretary, F. W. Kolb, 598 Monadnock Bldg., San Francisco 5.

**Illinois:** Organized, 1906. Headquarters, Chicago, Ill. Meets, Second Monday. President, James S. Locke, 433 E. Erie St., Chicago 11. Secretary, C. M. Burnam, Jr., Room 1605, 6 N. Michigan Ave., Chicago 2.

**Indiana:** Organized, 1943. Headquarters, Indianapolis, Ind. Meets, Fourth Friday. President, G. B. Supple, Architects and Builders Bldg., Indianapolis. Secretary, T. R. Davis, 1311 N. Drexel Ave., Indianapolis 1.

**Iowa:** Organized, 1940. Headquarters, Des Moines, Ia. Meets, Second Tuesday. President, B. E. Landes, 1603 47th St., Des Moines 10. Secretary, C. A. Wheeler, 511 Fifth Ave., Des Moines.

**Kansas City:** Organized, 1917. Headquarters, Kansas City, Mo. Meets, First Monday. President, R. B. Mason, 2014 Wyandotte St., Kansas City. Secretary, P. C. Leffel, 316 E. 75th St., Kansas City.

**Manitoba:** Organized, 1935. Headquarters, Winnipeg, Man. Meets, Third Thursday. President, F. T. Ball, 324 Main St., Winnipeg. Secretary, D. S. Swain, 27 Faweett Ave., Winnipeg.

**Massachusetts:** Organized, 1912. Headquarters, Boston, Mass. Meets, Third Tuesday. President, D. M. Archer, 143 Federal St., Boston 10. Secretary, A. Ehrenzeller, 23 Parklawn Rd., Boston 32.

**Memphis:** Organized, 1944. Headquarters, Memphis, Tenn. Meets, First Monday. President, T. J. O'Brien, 1030 Exchange Bldg., Memphis. Secretary, A. T. Bevil, 1521 Waverly Ave., Memphis 6.

**Michigan:** Organized, 1916. Headquarters, Detroit, Mich. Meets, First Monday after 10th of month. President, R. F. Connell, 1500 United Artists Bldg., Detroit 31. Secretary, A. E. Knibb, 1003 Maryland Ave., Detroit 30.

**Minnesota:** Organized, 1918. Headquarters, Minneapolis, Minn. Meets, First Monday. President, R. E. Gorgen, 2120 W. Cedar Lake Blvd. Secretary, O. L. Lilja, 5000 16th Ave. S., Minneapolis 7.

**Montreal:** Organized, 1936. Headquarters, Montreal, Que. Meets, Third Monday. President, A. B. Madden, 1170 Beaver Hall Sq., Montreal, Que. Secretary, S. W. Salter, 910 New Birks Bldg., Montreal, P.Q.

**Nebraska:** Organized, 1940. Headquarters, Omaha, Nebr. Meets, Second Tuesday. President, D. E. McCulley, 814 S. 14th St., Omaha 2. Secretary, D. D. Williams, Rm. 311, Federal Bldg., Omaha.

**New York:** Organized, 1911. Headquarters, New York, N. Y. Meets, Third Monday. President, H. J. Ryan, 101 Park Ave., New York 17. Secretary, Carl H. Flink, Room 3000, 51 Madison Ave., New York 10.

**North Carolina:** Organized, 1939. Headquarters, Durham, N. C. Meets, Quarterly. President, K. W. Selden, Jr., 701 Builders Bldg., Charlotte 2. Secretary, E. S. DeWitt, 1211 Commercial Bank Bldg., Charlotte.

**North Texas:** Organized, 1938. Headquarters, Dallas, Tex. Meets, Third Monday. President, E. J. Stern, 701 Burt Bldg., Dallas 1. Secretary, B. S. Foss, Jr., 401 Magnolia Bldg., Dallas 1.

**Northern Ohio:** Organized, 1916. Headquarters, Cleveland, Ohio. Meets, Second Monday. President, G. B. Priester, 10900 Euclid Ave., Cleveland 6. Secretary, R. L. Byers, 448 Terminal Tower, Cleveland 13.

**Oklahoma:** Organized, 1935. Headquarters, Oklahoma City, Okla. Meets, Second Monday. President, Earle W. Gray, Third & Harvey Sts., Oklahoma City. Secretary, G. T. Donceel, Oklahoma Natural Gas Co., Oklahoma City.

**Ontario:** Organized, 1922. Headquarters, Toronto, Ont. Meets, First Monday. Acting President, V. J. Jenkinson, 117 Peter St., Toronto 2B. Secretary, H. R. Roth, 57 Bloor St., W., Toronto, Ont.

**Oregon:** Organized, 1939. Headquarters, Portland, Ore. Meets, Thursday after First Tuesday. President, F. F. Urban, 6726 S. W. Burlingame Ave., Portland. Secretary, E. R. Lokey, 1238 N. W. Glisan St., Portland 9.

**Pacific Northwest:** Organized, 1928. Headquarters, Seattle, Wash. Meets, Second Tuesday. President, D. C. Griffin, 717 Lloyd Bldg., Seattle 1. Secretary, C. W. Finn, 702 Lloyd Bldg., Seattle 1.

**Philadelphia:** Organized, 1916. Headquarters, Philadelphia, Pa. Meets, Second Thursday. President, R. D. Touton, Ninth & Columbia Ave., Philadelphia. Secretary, F. H. Buzzard, 213 S. Broad St., Philadelphia 7.

**Pittsburgh:** Organized, 1919. Headquarters, Pittsburgh, Pa. Meets, Second Monday. President, L. S. Maehling, 778 Country Club Dr., Pittsburgh 16. Secretary, E. H. Riesmeyer, Jr., 231-33 Water St., Pittsburgh 22.

**Rocky Mountain:** Organized, 1944. Headquarters, Denver, Colo. Meets, First Wednesday. President, G. D. Maves, 1550 Glencoe St., Denver 7. Secretary, Fred Janssen, 1123 W. Third Ave., Denver 9.

**St. Louis:** Organized, 1918. Headquarters, St. Louis, Mo. Meets, First Tuesday. President, W. J. Oonk, 4548 Red Bud Ave., St. Louis 15. Secretary, W. A. Russell, 7918 Kingsbury Blvd., Clayton 5, Mo.

**South Texas:** Organized, 1938. Headquarters, Houston, Tex. Meets, Third Friday. President, J. A. Walsh, P. O. Box 1773, Houston. Secretary, D. M. Mills, Gray & Crawford, Houston 3.

**Southern California:** Organized, 1930. Headquarters, Los Angeles, Calif. Meets, Second Wednesday. President, Maron Kennedy, 5051 Santa Fe Ave., Los Angeles 11. Secretary, R. A. Lowe, 3744 Potomac Ave., Los Angeles 16.

**Utah:** Organized, 1944. Headquarters, Salt Lake City, Utah. Meets, First Wednesday. President, H. G. Richardson, 1433 Harvard Ave., Salt Lake City. Secretary, E. V. Gritton, 2470 S. 15th East St., Salt Lake City.

**Washington, D. C.:** Organized, 1935. Headquarters, Washington, D. C. Meets, Second Wednesday. President, W. H. Littleford, 616 New York Ave., N. W. Secretary, J. N. Stewart, 6124-32nd Pl., N. W., Washington 15, D. C.

**Western Michigan:** Organized, 1931. Headquarters, Grand Rapids, Mich. Meets, Second Monday. President, H. J. Metzger, 137 E. Water St., Kalamazoo. Secretary, H. W. Wolters, 830 Staples Ave., N. W., Kalamazoo 54.

**Western New York:** Organized, 1919. Headquarters, Buffalo, N. Y. Meets, Second Monday. President, F. A. Moesel, 31 Main St., Buffalo 3. Secretary, E. P. Heckel, Jr., 490 Broadway, Buffalo 4.

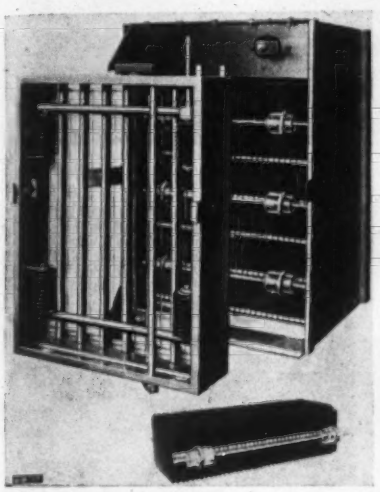
**Wisconsin:** Organized, 1922. Headquarters, Milwaukee, Wis. Meets, Third Monday. President, O. A. Trostel, Route No. 2, Thiensville. Secretary, J. R. Vernon, 507 E. Michigan St., Milwaukee 2.

## EQUIPMENT DEVELOPMENTS

*For your convenience in obtaining more information about any of this equipment, see coupon on this page. Add the new products and companies listed here to your Directory Section which you received in your January 1946 Heating, Piping & Air Conditioning and thus keep your records of sources of supply up to date throughout the year. Single asterisk indicates equipment not listed in Directory Section; double asterisk equipment and manufacturer not listed.*

### Unit Type Electronic Air Filter

No. 3008—The "Electro-Cell" is a unit type electronic air filter incorporating removable collector plate assemblies and is one of the latest of this type offered by the American Air Filter Co., Inc., 107 Central Ave., Louisville 8, Ky.

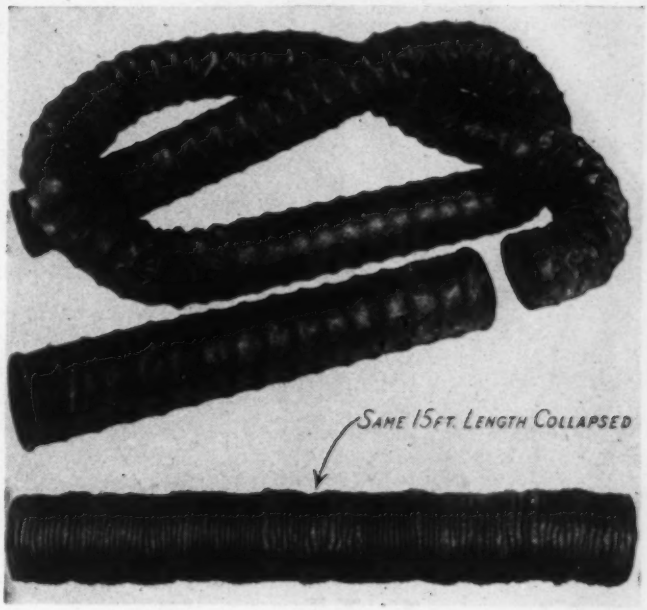


The positive and negative collector plates are assembled on cross rods to form horizontal groups which may be readily removed from the filter casing. Sliding into the filter casing in much the same manner as a desk drawer, plate assemblies can be removed for cleaning and re-oiling at convenient water and drainage locations. By keeping a spare set of plates, sufficient for one section, for use as a replacement, the length of time the filter is out of service is reduced to a minimum and the dirty collector plate assemblies can be cleaned at the convenience of the maintenance department. An automatic washing device has been developed permitting collector plate assemblies to be washed in place for installations where manual washing is not feasible.

The ionizers of the unit extend the full height of the sections, thus reducing electrical losses by having fewer wire ends, says the manufacturer. Standard sections are 2 and 3 in. in width with a capacity of 1000 cfm—capacities thus ranging from this minimum per unit to as many sections as are needed for the installation. The construction of the filter is such that it eliminates the duplication of top and bottom sections of box-like units when assembled one upon another. This is accomplished by the manufacture of the filter in a variation of heights from a minimum of 27 in. to a maximum standard height of 15 ft by 9 in. increments.

### Ventilating Hose

No. 3009—"Portovent" ventilating hose has been developed to meet the need for metal reinforced lightweight large diameter ducts which can be compressed into small space for transportation and yet stay open around sharp bends, says the manufacturer, the American Ventilating Hose Co., 15 Park Row, New York 7, N. Y. It is said to be particularly well suited for use with portable manhole and tank ventilators as well as portable air conditioning, heating, and cooling units.




The construction is sectional, allowing the assembly of any desired length from 2½ ft sections which may be coupled and uncoupled with the hands. It is claimed that a tight joint is formed in this way which will not be broken by jerks or pulls encountered in service. This "Neoprene" base hose is offered in sizes from 2-24 in. diameter.

### Indicating Flow Meter

No. 3010—The Hays Corp., 782 E. 8th St., Michigan City, Ind., has announced the "Veriflow Meter" for measuring, indicating, and totalizing various liquids used in industry. The outstanding feature of the new meter is said to be its ability to indicate the rate of flow at a point remote from where the meter is installed. This is in addition to the rate of flow indication and integrator which are integral with the meter itself. No

[*Continued on p.* 170]

Heating, Piping & Air Conditioning, [2-46]
6 N. Michigan Ave., Chicago 2, Ill.

Please ask the manufacturers to send me more information about the equipment mentioned under the following reference numbers in Equipment Developments and Recent Trade Literature.

*(Circle each number in which you are interested)*

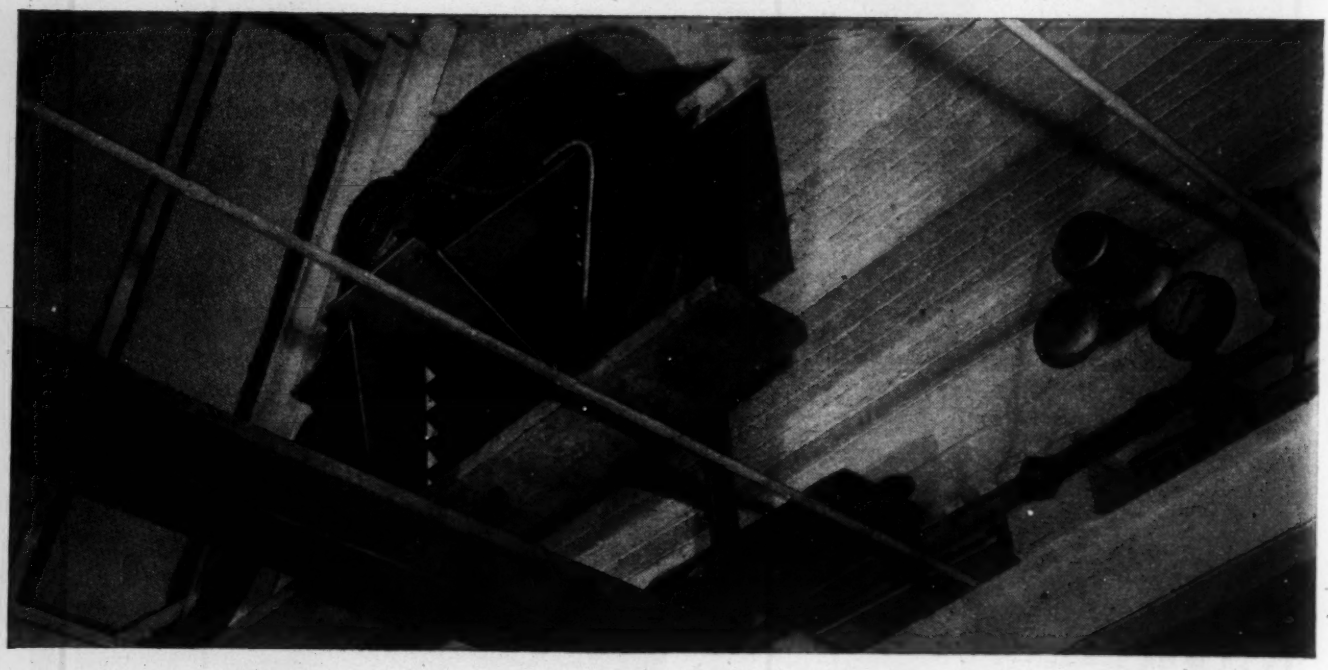
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3008 | 3009 | 3010 | 3011 | 3012 | 3013 | 3014 | 3015 | 3016 | 3017 |
| 3018 | 3019 | 3020 | 3021 | 3022 | 3023 | 3024 | 3025 | 3026 | 3027 |
| 3028 | 3029 | 3030 | 3031 | 3032 | 3033 | 3034 | 3035 | 3036 | 3037 |
| 3038 | 3039 | 3040 | 3041 | 3042 | 3043 | 3044 | 3045 | 3046 | 3047 |
| 3048 | 3049 | 3050 | 3051 | 3052 | 3053 | 3054 | 3055 | | |
| 6068 | 6069 | 6070 | 6071 | 6072 | 6073 | | 6075 | 6076 | 6077 |
| 6078 | 6079 | | | | | | | | |

Name..... Title.....

Company .....

Address .....

City..... Zone..... State.....



# Good Ventilation can be Simple

Good ventilation—plenty of clean, fresh air at the right places—means just one thing . . . *air movement.* It's not how much the equipment *costs,* or how *big* it is, that counts. It's *movement* that matters, and movement means operating efficiency.

### FOR WALLS, ROOFS, WINDOWS, DUCTS

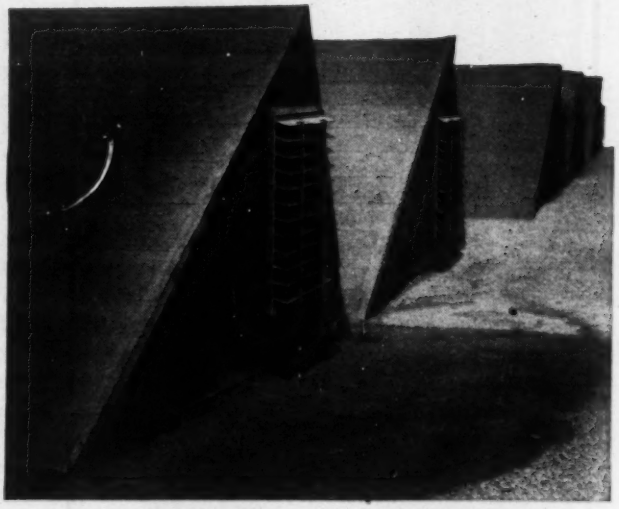
Propellair airfoil fans offer sure and *simple* solutions to industrial ventilating problems. Here is an application of direct-connected fans installed in a saw-tooth roof. Each fan is a *complete,* self-contained unit—easily mounted. Propellair automatic outside louvres open when fan starts; close when fan stops. There is nothing to get in the way—nothing to get out of order.

### KEEPS WORKERS HAPPY, HEALTHY, ON THE JOB

This plant makes millions of closures per day for a food product. Smoke and fumes from the hot waxing operation would quickly foul the air if not *completely* removed. So, when the ventilating equipment first installed *failed* to do the job, seven of these Propellair fans were put to work. They delivered such satisfactory performance that three more have since been added.

### MARVELS OF EFFICIENCY

Propellair airfoil fans don't *fan the air*—they *move* it, and with minimum h.p. for maximum c.f.m. Like modern aircraft wings, *both* blade surfaces create air movement—the back even *more* than the front. That's why Propellair fans are so remarkably efficient on *every* ventilating assignment. You'll like them.



**Installed behind these wide opening louvres are ten Propellair fans. Three are 36" diameter, seven 48" diameter. In addition to disposing of smoke and fumes, powerful air suctions also keep the plant dust-free, a requirement where production is for use with a food product.**

## *You Should Have This Free Book*

Send for this free, 72-page book of ventilating information—facts, figures, tables, and charts by a leader in the field, for quick and reliable reference—and the complete line of modern Propellair equipment for industrial ventilation. Ask us for the name of your nearest distributor, and for Book No. 10-HPAC.

**PROPELLAIR, Inc.** *"Moving Air is our Business"* SPRINGFIELD · OHIO

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# It's FREE!

This handy Melting Point Indicator for Solder is yours for the asking. Gives melting points in Centigrade and Fahrenheit for 98 different tin-lead alloys. The reverse side gives comparisons of wire gauges from 0000 to 40.

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**Federated Metals Division—Dept. H.P.A.C.-2**
**American Smelting and Refining Company**
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***Please send me a FREE Melting Point Indicator.***

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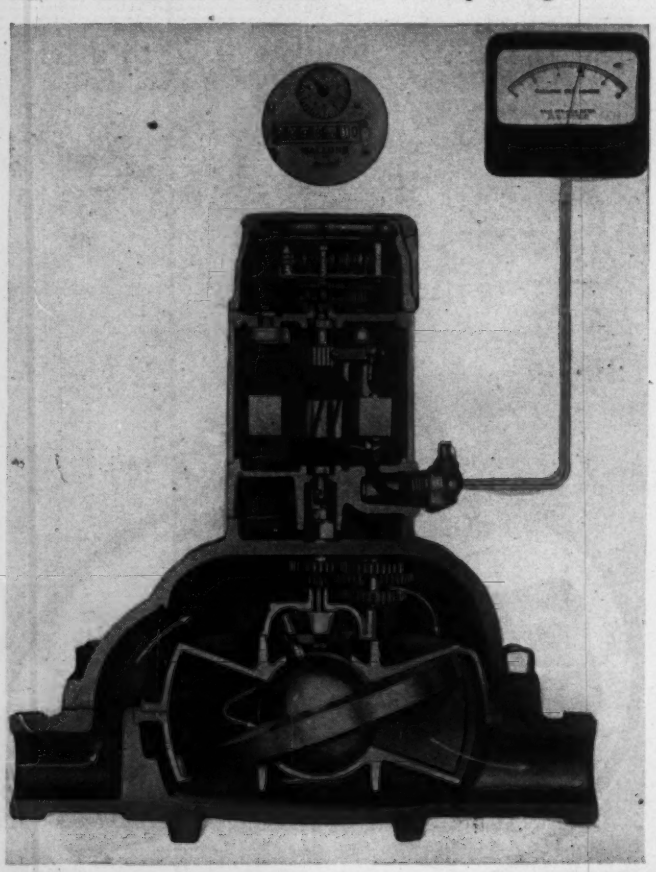
**WHEN you need non-ferrous metals remember Federated. We produce Ingot Metals and White Metal alloys in all standard specifications. Special alloys to your order.**

**ALUMINUM BRASS BRONZE**
**DIE CAST ALLOYS SOLDER**
**BABBITT TYPE METAL ZINC DUST**

[*Continued from p.* 167]
external source of electricity is required because the indicating meter measures the output of the generator and is calibrated to indicate the corresponding rate of liquid flow through the meter. The scale of the indicator can be calibrated to read in any values of flow desired such as gpm.



The new meter is offered for many applications, such as measuring, indicating, and totalizing the flow of oil, in testing hydraulically operated mechanisms, the flow of water in chemicals in continuous manufacturing processes, the flow of a heating or cooling liquid, and the blending of two or more liquids (proportioning).

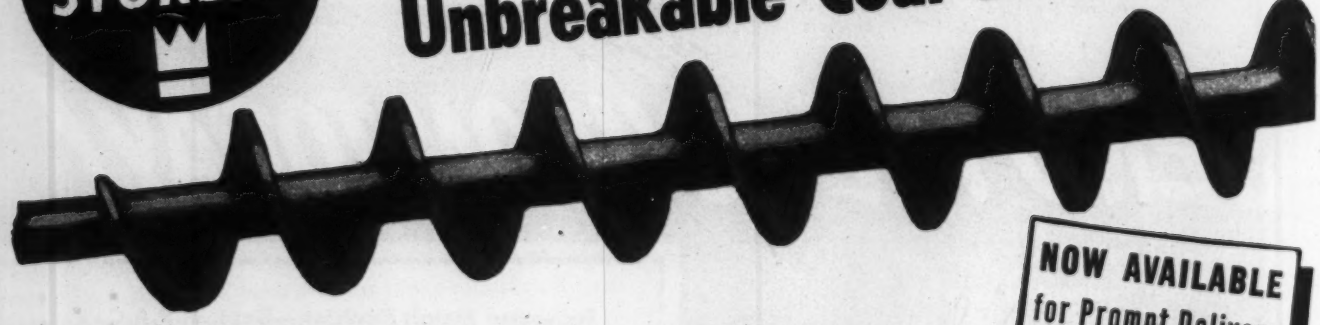
### High Pressure Steam Valves

No. 3011—Crane Co., 836 S. Michigan Ave., Chicago 5, Ill., has announced a new line of valves, designed for high pressure, high temperature steam service, primarily in the 1500 lb and 900 lb pressure classes, with welding ends, and embracing gate, globe, angle, and automatic stop-check valves. The design is said to incorporate important changes and some departures from previous conventional types of construction. Among the features claimed are:

1) The pressure seal bonnet joint utilizes the pressure in the valve to seal the joint and to eliminate leakage. Maintenance is reduced to a minimum because there is no need


For STOKERS

The CROWN Unbreakable Coal Feed Screw



NOW AVAILABLE for Prompt Delivery

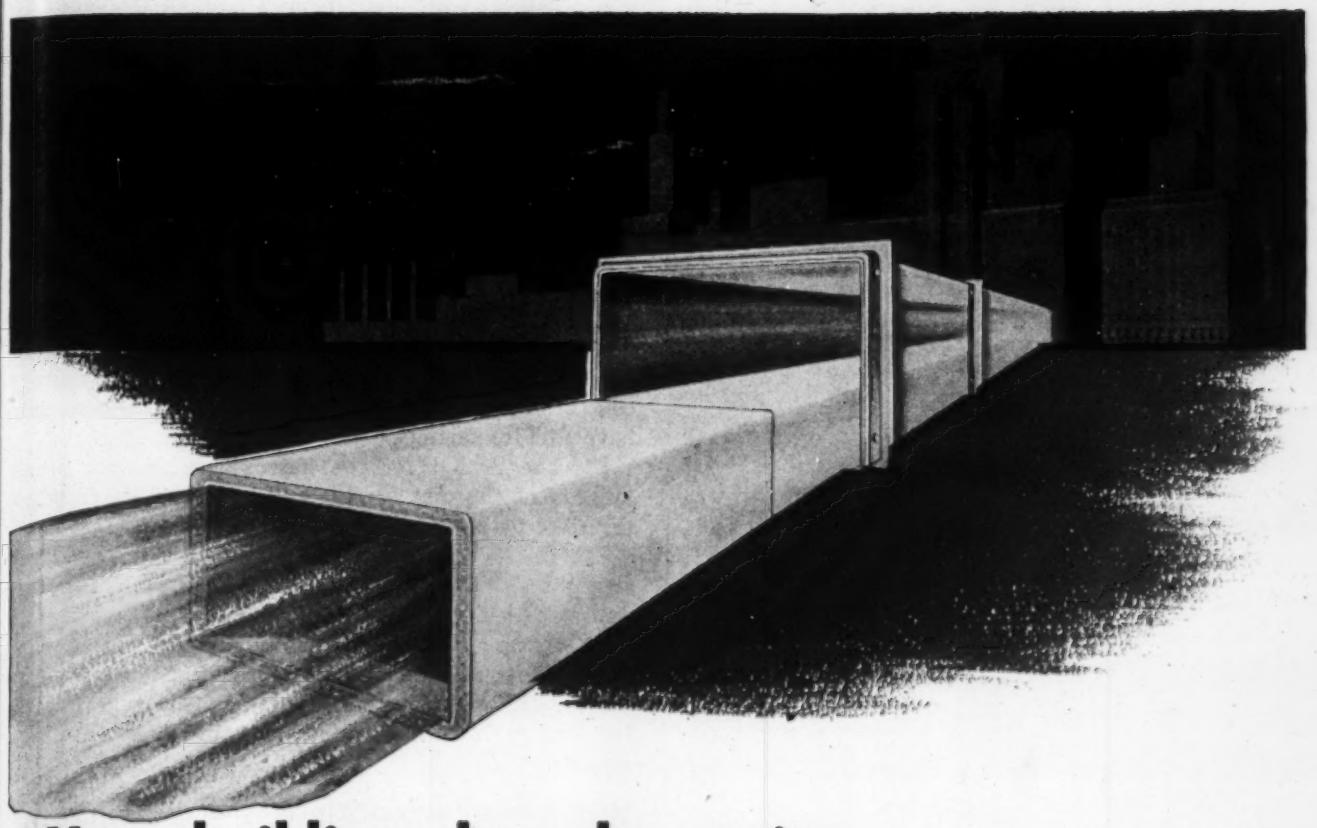
WELDED All-Steel Worm—All Sizes—All Pitches

★ Crown's complete line of all-steel Coal Feed Screws meets every replacement and production requirement. Produced for both domestic and industrial stokers. Crown Screws are available with right or left hand screws, in all sizes and pitches, tapered or straight, and in combinations of pitches. Uniformly smooth surfaces insure that coal will flow freely and easily through the flights. Because it is all-steel with continuous weld, the Crown Coal Feed Screw guarantees long, continuous operation with full customer satisfaction. Crown is in a position to make prompt delivery on all sizes.

*In ordering give complete specifications on size and design.*

CROWN IRON WORKS COMPANY

1202 Tyler St., N. E. *Since 1878* Minneapolis, Minn.



# Now buildings breathe easier . . . through *smaller "windpipes"*

**BLOW HOT! BLOW COLD!** Careyduct will deliver the load with minimum change in temperature.

**40% TO 80% QUIETER.** Careyduct carries higher velocities . . . means greater capacity.

Duct work requires space, and space is often tightest where it's needed most. Careyduct solves tight situations because it handles higher velocities quietly and efficiently—more air through smaller ducts.

This insulated, fire-resistant duct has other valuable characteristics, too. It reduces condensation—doesn't "sweat." It outlives and outperforms ordinary duct for many types of difficult loads. It's installed fast and easy—looks neater.

Being non-resonant it smothers the noises of fast moving air as well as that of blowers, fans, motors and other machinery.

Engineering service is available through Carey branch offices. For detailed information write direct to—

**INSTALLED FASTER** than ordinary duct . . . by any qualified sheet metal worker.

**GOOD LOOKING.** No unsightly joints. Takes any finish or looks good unfinished.

THE PHILIP CAREY MANUFACTURING CO.
LOCKLAND, CINCINNATI 15, OHIO

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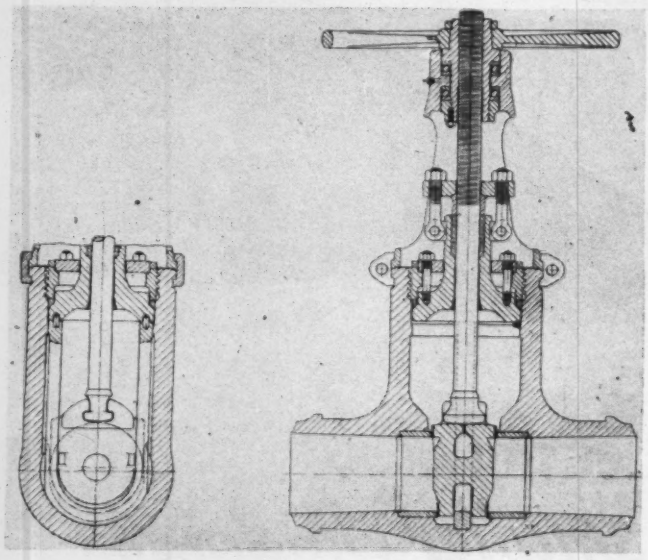
Built-up Roofing • Roof Coatings and Cements • Waterproofing Materials • Asphalt Tile Flooring • Pipeline Felt
Expansion Joint • Asbestos Wallboard and Sheathing • Corrugated Asbestos Roofing and Siding • Miami-Carey Bathroom Cabinets and Accessories

for pulling up bonnet joints by re-stressing the studs, either initially or periodically, as in the case of flanged bonnet joints.

2) Inspections of the interior of valves is expedited by the ease with which the bonnet joint can be taken apart and reassembled. Considerably less time is required to disassemble this new type of joint and to put it together again than for any bolted flanged joint.

3) The reduction in weight of 1500 lb pressure seal bonnet valves, for example, varies from approximately 40 to 60 per cent, according to size, when compared with conventional bolted bonnet valves of similar types. This new design of valves also permits an appreciable saving in space due to the elimination of heavy flanges and the resultant compactness and shorter end to end dimensions.



4) The application of insulation is made easier due to the streamlined design and particularly because the bulky flanged bonnet joint is eliminated. Less insulating material and labor will be required and a neater appearance will be achieved.

5) A new design of disc for gate valves has built in flexibility. This feature eliminates sticking of the disc and requires less torque for opening when the valve is cold after having been closed while hot. These discs have Stellite facings.

6) The design for the gate valves insures proper guiding of the disc for the full length of its travel on the close fitting machined guide.

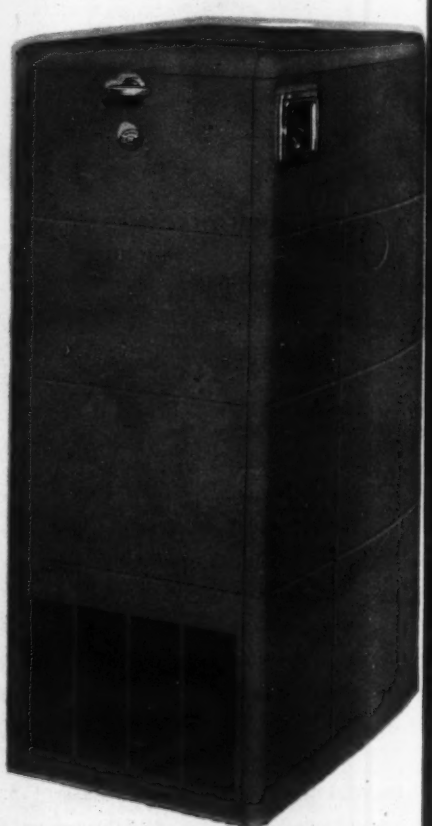
7) The body rings are also new in design, permitting straight line flow with minimum friction. They are seal-welded in place and Stellite faced.

8) A simple clamp, in sizes 8 in. and larger, eliminates the conventional type of construction which involves bolting the yoke to the body. The yoke is made integral with the retaining ring in sizes 6 in. and smaller.

### Non-Electric Stainless Steel Magnet

No. 3012**—The development of a non-electric magnetic separator with a working surface made of stainless steel is announced by Eriez Mfg. Co., Erie, Pa. It is said to offer a simple and efficient means of removing both large and small pieces of iron and steel trash


AGAIN, YOU'RE A STEP AHEAD
. . . with CLIMATROL GAS BOILERS



**New, improved Type 10 and Type 11 live up to Mueller's reputation for gas-heating progress**

Those extra selling points that help to clinch the sale — that smart, modern appearance your customers expect in new post-war equipment — again assure you of a competitive advantage when you promote Mueller Climatrol gas boilers. Completely redesigned and restyled. Equipped with new, extremely quiet burner and many other features that improve performance. Type 10 (illustrated) has controls completely enclosed, on Type 11 the controls are exposed. Suitable for residences and smaller commercial installations. For results that are a credit to you, recommend Climatrol. Write for bulletin F-320. . . .
*L. J. Mueller Furnace Co., 2007 W. Oklahoma Ave., Milwaukee 7, Wis.*

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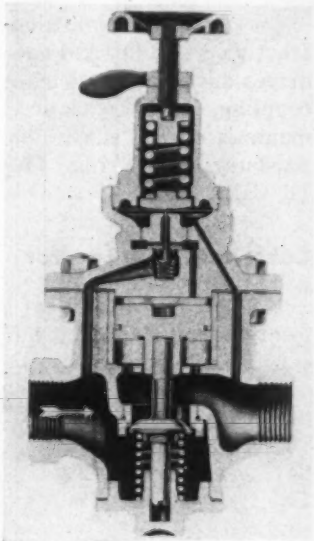
Mueller Climatrol
REG. U. S. PAT. OFF.
GAS BOILERS

from ingredients used in many industrial processes. Installed, for example, at any point where raw materials enter a chute or conveyor, it will attract and hold ferrous foreign bodies, preventing them from falling into machinery where they might cause damage.

This magnet may also be installed in the bottom of a steel trough, pipe line, or liquid feeding equipment, for removing ferrous particles from liquids and slurries, preventing material spoilage.

### Air Reducing Valve

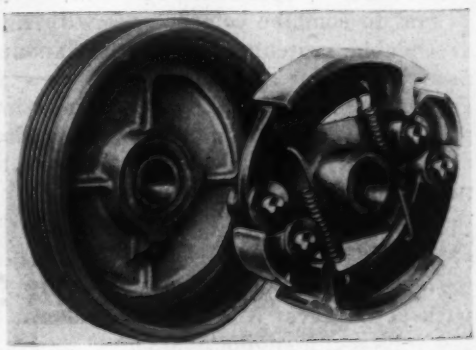
No. 3013—A new improved type of internal pilot operated reducing valve, known as "Class L-1A," has been announced by the Leslie Co., Valley Brook and Grant Aves., Lyndhurst, N. J., manufacturers of regulators, controllers and whistles. Among the features claimed for this new valve are its stability under all flow conditions, its quick responsive reaction to wide and sudden variations in load, and steady, accurate regulation and tight closing in dead-end service. Plastic inserts in the valve seats are said to provide positive tight shutoff and long life.



All wearing parts are renewable and complete interchangeability facilitates overhauling without removal from the pipe line. Corrosion and wear resistance is obtained by the use of stainless steel main valve, bronze controlling valve, and corrosion resistant piston rings. The new valve is available in sizes ½ through 4 in. inclusive, and is designed for initial air pressures up to 400 psi and reduced pressures from 5 to 300 psi. A similar valve designed for accurate control of small air quantities is known as class "JA-1" in ¼, ⅜ and ½ in. sizes and is similar in construction except that a neoprene diaphragm is used in lieu of the bronze piston. This valve has the same initial pressure range and will control reduced pressures from 1 to 300 psi.

### Automatic Clutch

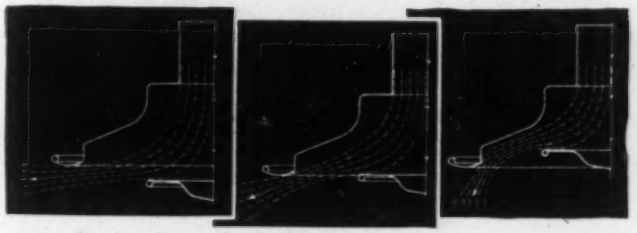
No. 3014*—To eliminate the sudden shock of starting machinery or moving equipment, a new, automatic clutch has been developed which can be installed directly on the shaft of any engine or electric motor. This mechanical clutch is said to offer the advantages of a fluid drive, but in addition, to permit complete




## How *adjustable* air diffusers increase the efficiency of supply air diffusion.

**Better mixing of room and supply air, more uniform temperatures throughout the occupied zone and noiseless, draftless air diffusion are accomplished with**

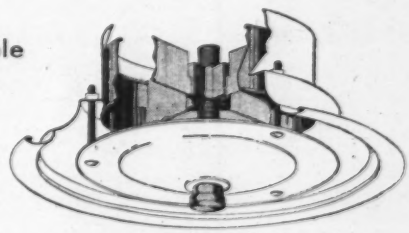
**KNO-DRAFT *adjustable* Diffusers**



**Any desired angle from vertical to horizontal at your fingertip.**

By simply turning the air adjustment screws (easily accessible from under the unit) the inner cone of any KNO-DRAFT Diffuser may be raised or lowered to secure any angle of air direction required by ceiling heights, system balancing, and individual or seasonal requirements. Thus the diffuser becomes more effective whether it is used in cooling, heating, ventilating, or combined systems, because it can expel chilled air parallel to the ceiling or eject heated air downward to prevent stratification.

**Type K** Adjustable Diffuser with Type D Volume Damper.



Pat. and pat. pending

**Any desired volume at your fingertip**

Every KNO-DRAFT Diffuser can be equipped with a built-in volume damper (easily adjusted by hand-turning knob under diffuser) which varies the outlet aperture uniformly without affecting the outlet velocity or diffusion pattern.

Thus KNO-DRAFT Diffusers can be adjusted quickly and accurately to the angle and volume needed to meet a wide variety of conditions, and as a result, the factors of temperature variation, temperature fluctuation, drafts and noise can be minimized considerably.

The W. B. Connor Engineering Corp. maintains a staff of specialists and district representatives in leading cities to assist you with any air distribution problem.

**FREE HANDBOOK**

Contains clear sketches, charts, dimension prints and instructive text that simplify the selection and installation of air diffusers.

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**W. B. CONNOR ENGINEERING CORP.**

*Air Diffusion* *Air Purification* *Air Recovery*

114 E. 32nd Street New York 16, N. Y.

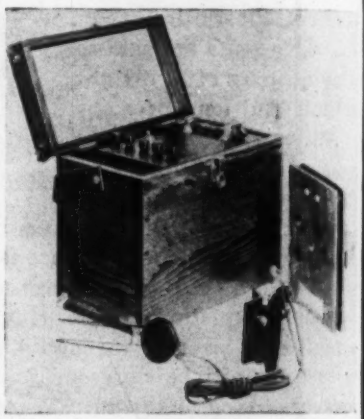
disengagement while idling and positive engagement when driving, with no possibility of slippage. In addition, improved starting and operating characteristics of machinery and appliances and elimination of overload stresses due to overcoming inertia are claimed.

The centrifugal principle, in simple form, is employed. The clutch is an opposed shoe type, dual-spring balanced, to give the desired degree of tension required for individual applications. Below a predetermined rpm of an engine or motor, the clutch idles. When the driving speed increases beyond the stipulated rpm, the expansion shoes press outwardly, contacting the friction lining of the drum.

Two models are available—one for the range from fractional to 3 hp, and one for use up to 6 hp. Different drives such as V-belt or flat belt pulley, gear, sprocket, coupling, or a variable speed transmission can be mounted on the shaft. This clutch is manufactured by Salsbury Motors, Inc., 4464 District Blvd., Los Angeles 11, Calif.

### Cable and Pipe Locator

No. 3015*—Additional features for determining the location and depth of buried pipe and cable are now offered with the "Stewart" cable tester, made by W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44, Ill. The original cable tester—designed for locating shorts, crosses, grounds, and wet spots—has been improved so that this instrument is said to indicate also the depth and locations of pipe and cable, and to be especially useful where installation records have been lost or destroyed. Another use, stressed by the manufacturer, is the determination of service pipe depth in relation to frost lines.



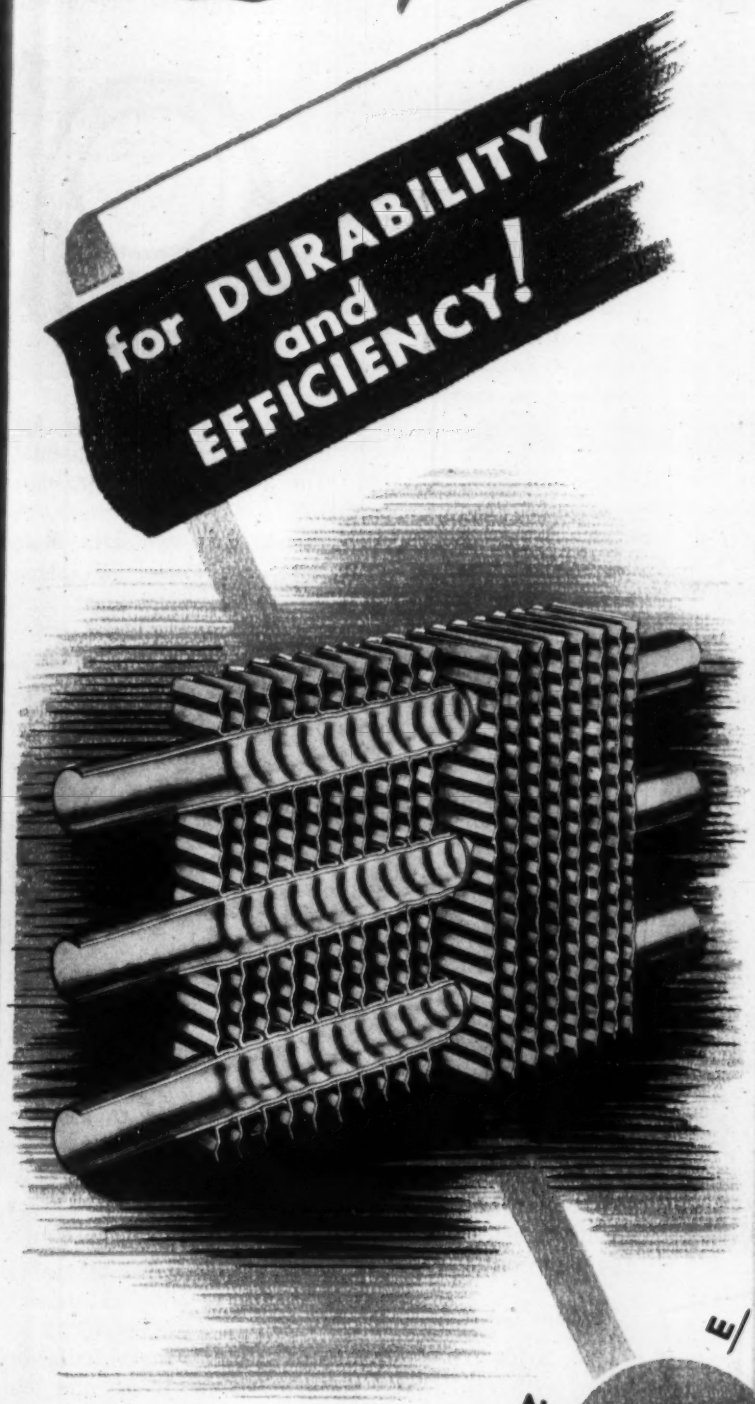
This portable locator is constructed for rough use and weather, weighs 22 lb, and is furnished with detector coil and neutral exploring coil.

### Control Relay

No. 3016**—Production of a new control relay, which is said to combine compactness with light weight and dependable switching, has been announced by Allied Control Co., Inc., 2 E. End Ave., New York 21, N. Y. Designated as the "CR" relay, it is claimed to be more efficient on precision application for industrial and special control circuits than larger and heavier relays. Among other features claimed are unusually large contacts (which can be obtained in silver or alloys).

Molded bakelite is used for insulation and a steel base is designed to provide rigidity. Contact rating with ¼ in. silver contacts is 15 amp at 24 volts d-c or 110 volts a-c, noninductive.

# McQuay RIPPLE FIN COILS




ONLY McQuay gives you Ripple Fin coils and only Ripple Fin coils give you top performance. Look at these distinct advantages:

•

*Ripple Fin coils have higher flexible strength with less air friction and cleaner operation.*

•

*Ripple Fin coils have greater heat transfer surface.*

•

*Hydraulic expansion of all tubes into fins having wide collars provides permanent mechanical bond.*

•

*Copper headers have strongest construction because of inherent flexibility to accomodate unequal contraction and expansion.*

•

McQuay coils are proved and preferred — proved by service under the most rigid conditions and preferred because of their exclusive construction.

•

McQuay coils are available in a wide variety of styles and sizes, both standard and special coils for steam, hot water, cold water, brine, direct expansion and other applications. For complete information write McQuay Inc., 1600 Broadway Street Northeast, Minneapolis 13, Minnesota. Representatives in all principal cities.

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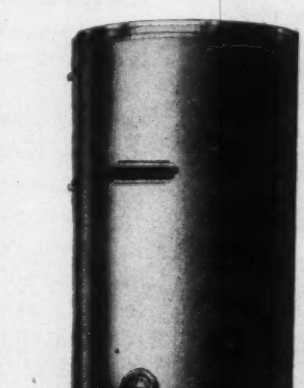
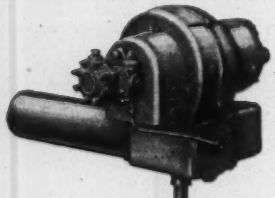
Aldrich Oil Burners and Burner-Boiler Units were standard equipment in United States Insular Bases the world around. That's proof of unmatched efficiency, performance . . . All during the war, Aldrich Co. worked night and day at their regular job—producing extra-value burners and burner-boiler units . . . Post war improvements are facts—not promises—in Aldrich equipment.

**HEAT-PAK Burners Models AX and BX**

Embodying famous Aldrich features, HEAT-PAK Model AX (.75 to 4.00 G. P. H.) and Model BX (3.00 to 8.00 G. P. H.) are being produced as fast as materials become available . . . Production of famous HEAT-PAK Burner-Boiler Units and oil-fired Water Heaters is limited only by manpower and materials.



*Aldrich*
COMPANY
WYOMING, ILLINOIS



**SERVICE-FREE**

Aldrich engineering genius, designing skill, and production experience combine to give you equipment that is practically service free. No wonder Aldrich led the industry in prewar volume! Look to Aldrich for leadership in oil-fired equipment.


### Air Flow Indicator

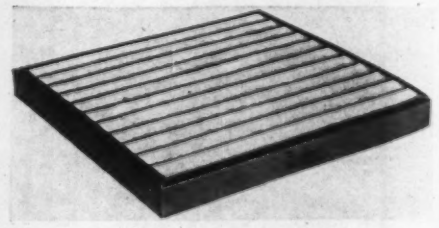
No. 3017*—Now in production at the Dollinger Corp., 9 Centre Park, Rochester 3, N. Y., is the "Flocator," a new and inexpensive air flow indicating instrument which has been designed for use in any ventilating system.

A vane in the air stream is used to rotate a shaft, which, in turn, is connected to an adjustable counter weight and indicating dial. According to the manufacturer, the counter weight is adjusted so that with clean filters and the entire system operating at maximum capacity, the instrument indicates 100 per cent flow. Any decrease in air flow will be indicated by the pointer, which shows, at all times, the percentage of maximum flow that is being obtained.

The device is being manufactured in two sizes, Model 45 for small capacity systems and Model 75 (shown here) for large systems.

### Replaceable Air Filter

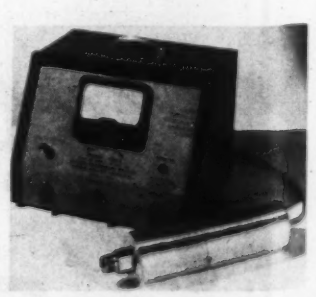
No. 3018—A new dry, replaceable type of air filter for domestic and commercial use in forced warm air and air conditioning units has been announced by the Badger Corp., 327 E. Brown St., Milwaukee 12, Wis. Made of odorless, fire-resistant glass fibre, the new filter is said to provide 25 per cent greater filtering surface because of an exclusive rib design.



Special flange construction is designed to assure a perfect air seal in the frame. Although lighter in weight than other replaceable filters, long life is assured by great rigidity and sturdiness of strong cardboard frame firmly cemented to exclusive rib structure, according to the manufacturer.

### Vacuum Gage

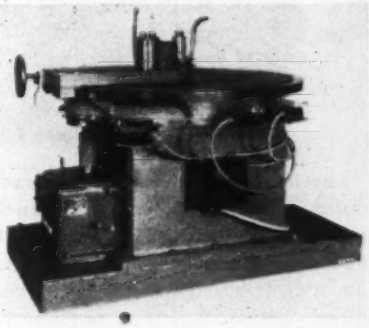
No. 3019—The "Alphatron" is an all metal ionization gage with continuous linear response to 10 mm total pressure. The ionizing agent is a stream of alpha particles emitted by a radioactive source which is said to permit operation at any pressure, including atmospheric, without damage to the gage. According to the manufacturer, the emission characteristic of the radioactive element and the amplifier design insure great stability and reduce



needle flicker to a minimum. The model produced at present by the National Research Corp., Vacuum Engineering Div., Boston, Mass., covers from 0 to 10 mm in three ranges, all reading direct pressure. The ranges are 0 to 0.1 mm, 0 to 1.0 mm, and 0 to 10 mm. Pressures can be read to one per cent of full scale reading in each case. The gage is suitable for measuring pressures of gases other than air, such as argon, water vapor, and hydrogen.

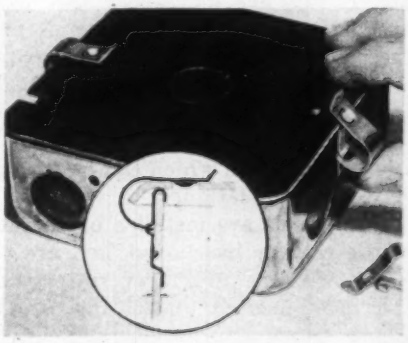
### High Speed Bending Machine

No. 3020—Pedrick Tool & Machine Co., 3640 N. Lawrence St., Philadelphia 40, Pa., is offering a new high speed production bender for copper tubing which is said to be suitable for making coils as well as simple bends. It can be equipped with a feed and synchronized straightener for bending coils directly from rolls of tubing and is designed to handle tubing in multiples.



### Box Cover Fastener

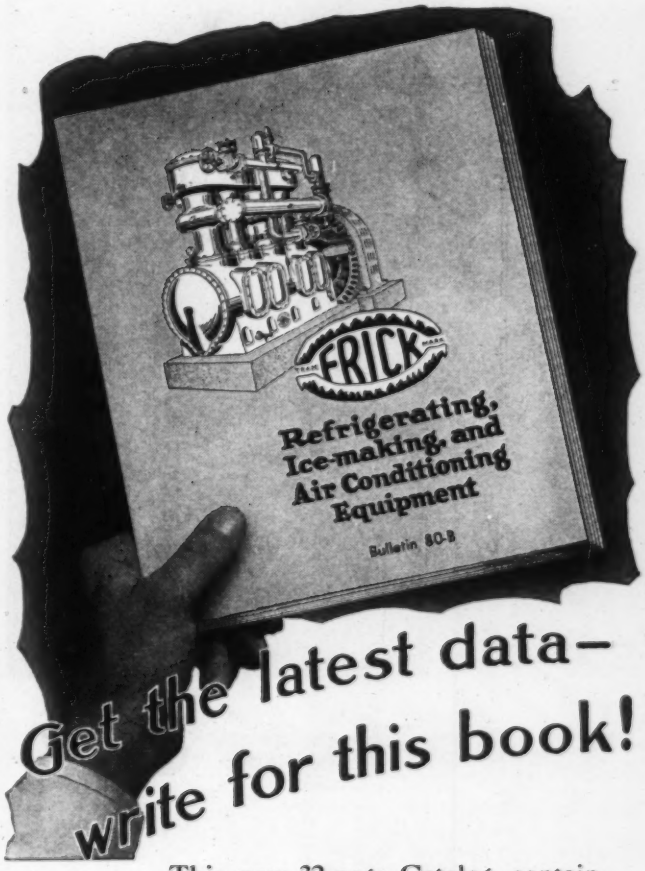
No. 3021—A spring steel fastener for box covers has been announced by Tinnerman Products, Inc., 2018 Fulton Rd., Cleveland 13, Ohio. According to the manufacturer, it eliminates all screws, nuts, and rivets, as well as tools for attaching. The clip is self retaining and is snapped by hand into prepunched holes in the sides of the box. By flipping the clips into locked position, the cover is held in place (as shown). To remove the cover, the clips may be unsnapped by pushing them back with the thumb, says the manufacturer. These fasteners are available for use on sheet metal, die cast, plastic, or plywood boxes of varying wall thicknesses.



### Humidity Indicator

No. 3022**—A self-adhesive sensitized disk which changes color, depending upon the moisture content of the air—blue when dry, pink when moist—has been made up in post card size with a color chart incorporating various shades of blue and pink to indicate moisture content of the air. The seven color gradations on the chart are labeled to indicate moisture conditions from dripping wet to completely dry.

The disks, known as "Hygrolables," are offered by the Eljay Enterprises, P. O. Box 891, Newark 1, N. J.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This new 32-page Catalog, containing over 150 photographs, diagrams, and tables, gives the very latest data on cooling systems of all commercial and industrial (not household) types.

The Bulletin is printed in 3 colors, in full letter size, and has a durable cover. As shown below, it is one of the most informative books ever published on refrigerating machinery.

If you need such equipment, ask for your copy of Bulletin 80-B today. In writing, please describe carefully the cooling work you wish to do.

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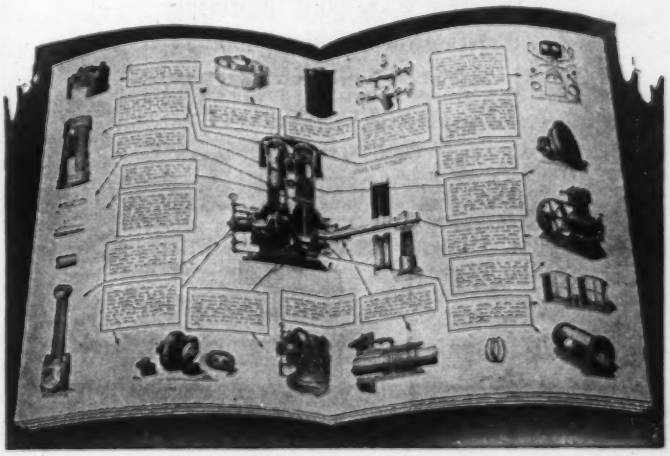


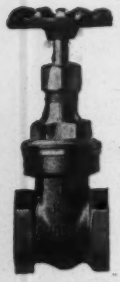
THE HEAT'S ON!

The third degree we're getting for our oldest plumbing items is really "something" (though not exactly like the picture, of course). Plenty uncomfortable, yet kind of flattering, too.

But here's the point . . .

We're anxious to produce the Gate and Radiator Valves we took over just before the war (former Eureka line). But with reconversion of our first few *plumbing items* taking our whole capacity—and still nowhere near enough—you can see why those items still have to be allotted . . . and also why we can't start our new Gate and Radiator Valves right now.

We're as anxious as you are to catch up with customers' needs . . . good service . . . prompt delivery. And, of course, you can count on the famous Eureka Gate and Radiator Valves on that basis as soon as possible. We still can't say exactly *when*. But just as soon as some of the heat is off of us, we can help you turn it on for your customers.



The Schaible Company

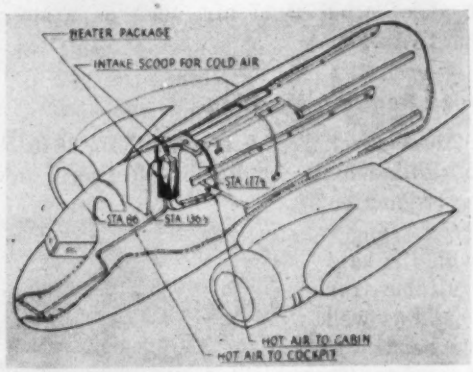
CINCINNATI 4, OHIO

MAKER OF QUALITY BRASS GOODS

STOCKED BY LEADING WHOLESALERS EVERYWHERE

## Aircraft Heating Package

No. 3023—A "Janitrol" aircraft heater package, designed to provide additional economies and improved standards of comfort in the Douglas DC-3 aircraft, has been announced by the Surface Combustion Corp., 2375 Dorr St., Toledo 1, O.




The unit contains a direct fired gasoline heater (maximum output, 125,000 Btu), fuel pump, spark ignition system, ventilating and combustion blowers, temperature controls, and other component parts. According to the manufacturer, cabin temperatures can be maintained within 2 deg of thermostat settings, and operation is independent of the plane's engines. Light weight and ease of servicing and inspection are among other advantages claimed.

## Baseboard Panel Heating Unit

No. 3024*—Burnham Boiler Corp., Main St., Irvington, N. Y., has announced the development and early production of the "Base-Ray Heat Panel." Replacing the conventional wooden baseboard, the new heat panel is designed to deliver radiant heat into the room at ankle height.

In appearance it is a hollow cast iron unit 7 in. high and 1¾ in. wide, which can be used on hot water, steam, or vapor installations.

The panels are installed on the outside walls in place of the regular baseboard, and are painted to match the room. The manufacturer states that tests demonstrate that this method of heating provides the most even room temperature ever achieved. Even in subzero weather the floor to ceiling differential is less than 3 deg.

Panels will be manufactured in 24 and 12 in. lengths and will be shipped assembled up to 10 ft. When longer panels are required, they will be shipped in two or more pieces to be assembled on the job. Sections are joined by means of push-nipple construction with short tie bolts. Valves, ells and traps are connected to the panels at bottom opposite ends, as with tube type radiators. These connections are concealed by a metal enclosure which is flush with the front and top of the panels. Standard wood moldings at top and bottom of the panel are designed to give it the same finish as the other baseboards in the room.

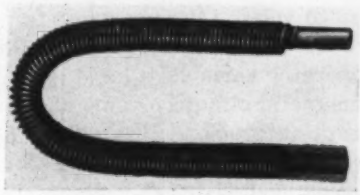
## Valve Company Expands

No. 3025—The Ashton Valve Co., 161-1st St., Cambridge 42, Mass., has acquired the valve division of the Lombard Governor Corp., Ashland, Mass. The line of new products offered consists of cast iron, steel, bronze,

and stainless steel relief valves for marine, petroleum, chemical and general industries.

### Stainless Steel Flexible Tubing

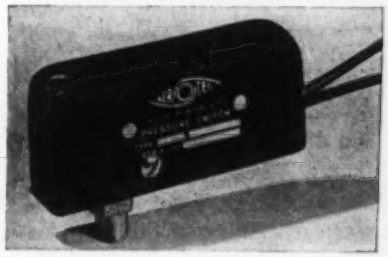
No. 3026*—A new flexible tubing of stainless steel has been announced by the Seamlex Co., Inc., 27-27 Jackson Ave., Long Island City, N. Y. As shown here, flexibility is provided by helical convolutions. Integral cylindrical extensions suitable for attaching flare type fittings are often used at the ends of sections, though many types of end connections can be furnished. Metallic braid jacketing is usually provided to take care of internal pressure requirements. Standard sizes range from 1/16 to 1/4 in ID.



### Industrial Pressure Switches

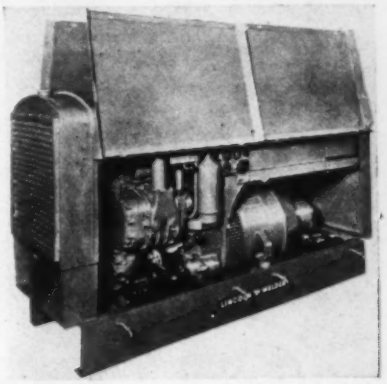
No. 3027—The Aerotec Co., White Plains, N. Y., has developed three new 8 oz switches for either vacuum or pressure up to 200 lb, in the control of liquids or gases that will not corrode brass.

Typical applications are to control compressors and pumps. They are rated at 10 amp, 110 volt a-c, and are available in three designs. Type M-500 has an externally adjustable range with a fixed differential. Type M-600 can be reset manually from the outside. Type M-700 has an adjustable differential. Contact arrangement in the first two can be specified as normally closed, normally open, or double throw. The third design is available only with normally open contacts. Pressure connection is by means of a ⅛ in. pipe nipple.



### Diesel Driven Welder

No. 3028—A new diesel engine driven welder of 300 amp capacity designed for use in locations where electric power is not available, or not economical, has been announced by the Lincoln Electric Co., 12818 Coit Rd., Cleveland 1, Ohio.



Powered by a two cycle diesel engine, this addition to the "Shield-Arc" welder line is said to cut fuel costs up to 86 per cent, depending upon the price of fuel oil used.

Engine features include a simplified fuel arrangement with complete fuel filtering system. Equipped with dual continuous control, this unit permits the operator to select any type of arc and any arc intensity to suit the job. This feature, says the manufacturer, improves the speed,

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CHROME LOCK GASKETING
*Saves Tying Time*

Scribe on Liner

Cut and Punch Thru Liner

Remove Liner When Ready to Use

Press Chrome Lock Firmly to Flange

NO NEED to tie, lace or tape your gaskets onto vertical or inverted flanges. Chrome Lock Gasketing has an adhesive back! You just finger-press it to the surface and it stays put! The liner on Chrome Lock Gasketing enables you to lay the template and either scribe or mark with ordinary lead pencil. Quantities of gaskets may be cut at one time and stacked without danger of sticking or collecting dirt. These exclusive Chrome Lock features save untold time and work . . . Investigate today.

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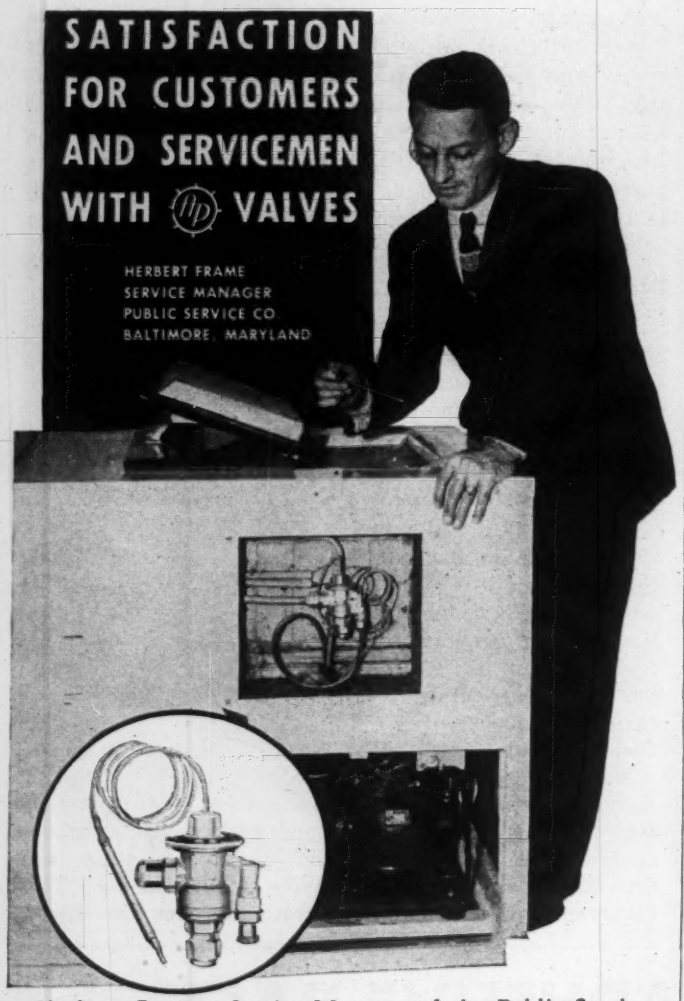


**Herbert Frame,** Service Manager of the Public Service Co., of Baltimore, shown above, is checking the temperature of an ice-cream cabinet on test. A standard "A-P" Thermostatic Expansion Valve Model 207 is used on this job as standard equipment.

**Writes Mr. Frame:** "A-P Valves for high and low temperature work have been used by our company since 1936. Customers' satisfaction as well as servicemen's satisfaction has been accomplished by the use of A-P Valves during this period."

**There is more** profit for servicemen and customers alike — with standard A-P Thermostatic Expansion Valves that can be used on low temperature, commercial temperature, and air conditioning work without adjustment.

**You have less** stock to carry, and your customers get better service — the kind that keeps them your customers year in and year out.

**Bulletins** covering all "A-P" Refrigeration Controls will be sent you upon request

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DEPENDABLE *Refrigerant Valves*

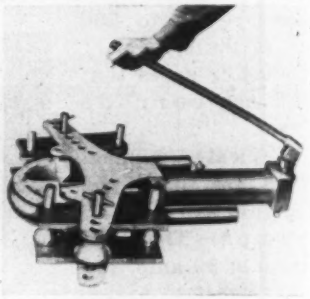
Stocked and Sold by Good Refrigeration Jobbers Everywhere
Recommended and Installed by Leading Refrigeration Service Engineers


quality, and ease of welding. Also, because of its fine adjustment, it makes possible a much wider range of application, both as to thickness and classes of metals and alloys. Other features of the welding generator include separate excitation and laminated magnetic circuit.

The welding generator has NEMA rating of 300 amp at 40 volts. Current range for welding duty is from 20 to 40 volts, 60 to 375 amp. The unit is of the single operator variable voltage type, with complete laminated magnetic circuit (frame and pole pieces) and equipped with interpoles. It requires no external reactance or stabilizer. Patented dual control of welding current is accomplished by adjustment of both series and shunt fields. Uniform welding current is supplied for metallic arc welding in any position with bare or heavily coated electrodes, also for carbon arc welding.

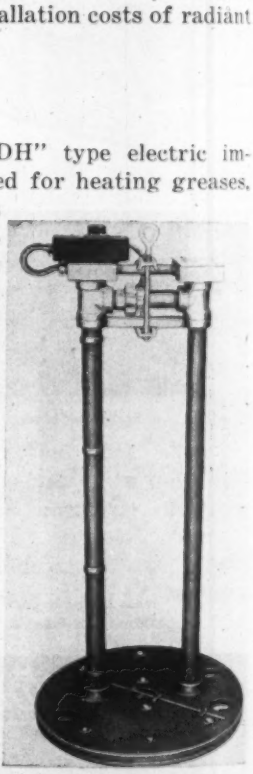
### 180 Deg Pipe Bending Device

No. 3029—Tal's Prestal Bender, Inc., 225 N. Water St., Milwaukee 2, Wis., has announced a new attachment for the company's portable bending machine. The new device is designed to bend any wrought iron or steel pipe ⅜ to 2 in. in diameter 180 deg in a single operation. According to the manufacturer, no stopping of the machine to move or shift pipe is necessary and the 180 deg bending operation is as easily performed as bends to a lesser radii. It is also claimed that the new attachment will speed up work and lower installation costs of radiant heating systems.



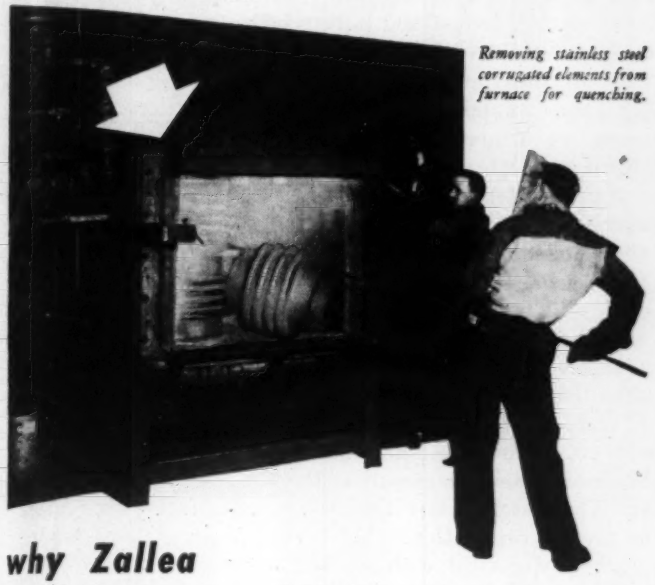
### Electric Immersion Heater

No. 3030—The "Chromalox DH" type electric immersion heater has been designed for heating greases, solid oil, and other compounds supplied in 55 gal drums or similar containers. The unit consists of a thermostatically controlled circular heating element, steel risers which allow all electrical connections to terminate in a standard conduit box, and an eye bolt at the top of the assembly for convenience in handling. According to the manufacturer, uniform heating is obtained by placing the heater in the drum and allowing it to melt its way to the bottom as the weight of the unit allows it to settle rapidly and the large heated area tends to eliminate cold regions.



This heater is available for 115 and 230 volt, single phase current in ratings up to 5000 watts and is offered by the Edwin L. Wiegand Co., 7610 Thomas Blvd., Pittsburgh 8, Pa.

# This is ONE big reason...



*Removing stainless steel corrugated elements from furnace for quenching.*

## why Zallea Corrugated Expansion Joints Endure

During fabrication and after the final forming operation all Zallea Expansion Joints are given a full anneal to remove all stresses left by the forming operation. Proper heat treatment is essential to secure the maximum potential life of any corrugated expansion joint.

Although this heat treatment varies with the metal, in every case the corrugated element must be slowly and uniformly heated to a pre-determined temperature, held there for a definite time, then cooled at a definite rate. Obviously, this cannot be accomplished by local annealing with torches—the method most often used in the manufacture of corrugated expansion joints.

All Zallea Expansion Joints are properly heat treated in gas-fired furnaces equipped with temperature controls capable of maintaining temperatures constant within 25° at any point up to 2000° F. Recorders provide a permanent record of each heat.

*Zallea Corrugated Expansion Joints are made in non-equalizing, self-equalizing and Duo-equalizing types, depending upon the conditions under which they must operate . . . of copper, stainless steels and other corrosion-resistant alloys . . . diameters from 3" upward . . . traverses up to 7½" . . . for pressures from vacuum to 300 psi . . . for temperatures from sub-zero to 1600° F.*

*For complete descriptions and specifications write for Bulletin 46 now in preparation, or ask us to quote on your requirements.*

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**ZALLEA BROTHERS & JOHNSON**
EQUIPMENT FOR THE PROCESS INDUSTRIES
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**Specify and Demand Furnace-Annealed Expansion Joints**

30% SAVING IN COSTS and a 500% increase in production are reported by this user of 16-Gage Electric "Porto-Shears."

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Black & Decker Electric "Porto-Shears" zip through jobs that are slow with snips . . . cut metals too tough for snips . . . make clean, smooth, accurate cuts with a big saving of time and trouble. Fast, powerful shearing action. Cutting operation always visible. Easy to follow straight lines, irregular patterns or curves down to ¾" radius.

Two "Porto-Shears" models—16 and 18 gage—cut up to rated capacity in steel or galvanized iron . . . about one gage thinner in Monel or stainless . . . 50% above rating in copper, aluminum, lead and other non-ferrous metals. Operate on A. C. or D. C.

See your Black & Decker Distributor about "Porto-Shears" and other electric tools for sheet metal work, or write to: The Black & Decker Mfg. Co., 628 Pennsylvania Ave., Towson 4, Maryland.

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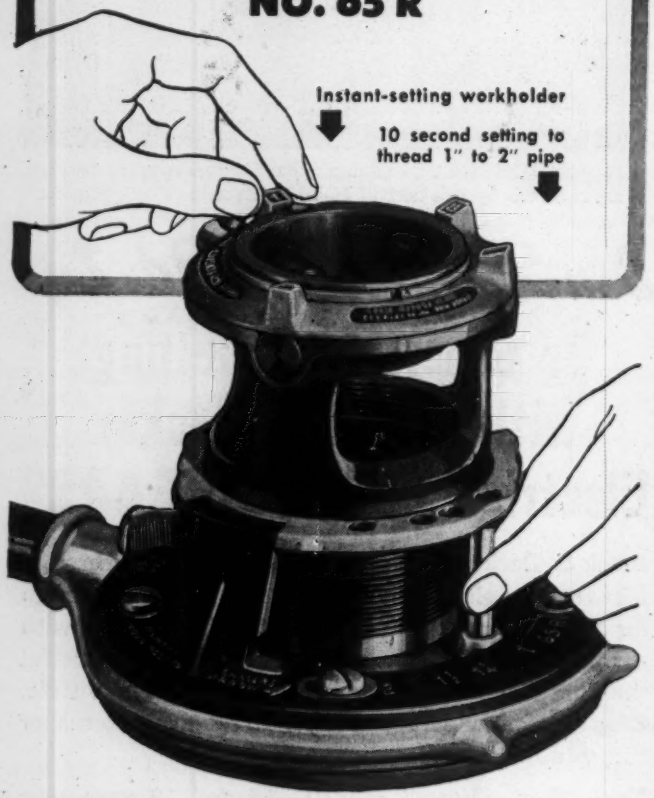
**Black & Decker**
PORTABLE ELECTRIC TOOLS

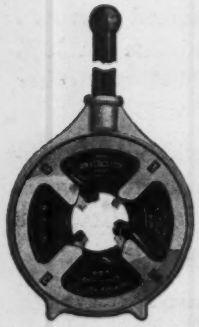
ELECTRIC DRILLS ELECTRIC SANDERS BENCH GRINDERS WIRE BRUSHES

You enjoy smoother, easier pipe threading with this self-contained semi-automatic . . . . .

RIDGID

NO. 65 R



*It stands up handily on the floor.*

● Precision-made and tested in every one of its 23 rugged steel-and-malleable parts, the 65R gives you fast, smooth, almost effortless pipe threading. Clean perfect 1", 1¼", 1½" and 2" threads with one set of high speed steel dies that adjust to size in 10 seconds. Workholder sets to pipe size instantly —1 screw and no bothersome bushings. You enjoy owning and using this modern threader — order from your Supply House.

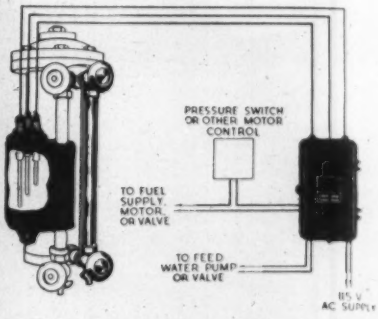
RIDGID

WORK-SAVER PIPE TOOLS

THE RIDGE TOOL COMPANY • ELYRIA, OHIO, U. S. A.


### Boiler Feedwater Control

No. 3031—The "Fireye Type B117N" feedwater control is designed to maintain automatically the water level on commercial and industrial boilers. It maintains the desired level through valve or pump control and cuts off the fuel supply and sounds an alarm at a predetermined low water level.




A probe fitting unit, which is mounted on the boiler, contains three probes. The top and middle ones determine the high and low levels at which the feedwater pump or valve is turned on and off. When the water falls below the middle probe, the unit closes the circuit controlling the pump or valve and feedwater enters the boiler. When the level rises to the top probe, the water itself acts as a conductor of a small electrical current which operates the control and turns off the pump or closes the feed valve. Should the water level fall below the lowest probe, the fuel supply is shut off and an alarm is sounded. The probe fitting which is mounted on the boiler is electrically connected to the feedwater control unit.

This control device, which has no moving parts, is offered by the Combustion Control Corp., 77 Broadway, Cambridge 42, Mass., and may be obtained for use on circuits of 115-230 volts, 60 cycles, a-c.

### Exposure Slide Rule for Photocopying

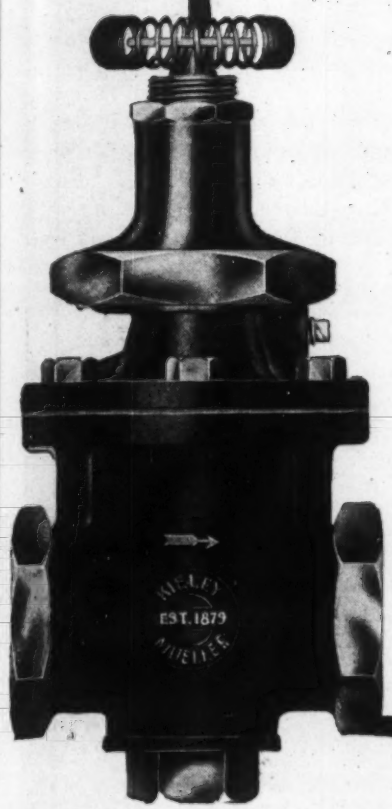
No. 3032—The American Photocopy Equipment Co., 2849 N. Clark St., Chicago 14, Ill., is distributing an exposure slide rule to owners of "Apeco" photocopy equipment. The varnished cardboard slide rule is designed to provide rapid calculation of exposure time for various types of reproduction such as positive, reflex, reverse, alternate, and readable negative and may be used for documents ranging from original tracings on very thin paper to newspapers, photographs, and blueprints.

### Flow Meters

No. 3033*—The Hays Corp., 782 E. 8th St., Michigan City, Ind., manufacturers of boiler room and industrial instruments and controllers, has announced that the flow meters formerly manufactured by the Cochrane Corp. of Philadelphia have become a part of the Hays line of products and will be sold by its representatives for flow, liquid level, pressure and temperature measurement.

The flow meters will continue to be manufactured in Philadelphia by The Penn Industrial Instrument Corp. —an organization comprised of the same men who have been responsible for the production of these meters for many years.

Daniel Meyer and Fred Skirving, who have been associated with the instrument division of the Cochrane Corp. for a number of years, have joined the Hays engineering staff and will specialize on flow meters and flow measuring problems.




# EXTREMELY ACCURATE REGULATION

## . . . EXTREMELY COMPACT IN SIZE

A fraction-turn of the handwheel—and you can control *exactly* the pressure of steam passing through this very compact K & M Reducing Valve. Model 481 is widely used for difficult reduction service in industrial processes—and as a primary valve in double reduction installations. Self-contained . . . made in bronze . . . available in valve sizes of ½" to 2"—with 5⅜" the maximum overall measurement, face to face! Yet it accurately controls inlet pressures up to 250 lbs. . . . maintaining constant reduced pressures of 2 lbs. to 80% of the inlet. If you have a tough pressure reduction problem, perhaps K & M #481 is the answer. Our Engineering Department invites your inquiries.

***Write for Catalog 66-C***

**KIELEY & MUELLER, INC.**

MANUFACTURERS OF PRESSURE AND LEVEL CONTROLS

**2015 43rd ST., NORTH BERGEN, N. J.**

*Awarded our employees for outstanding production achievement.*

# 3-WAY GUARANTEE OF DEPENDABLE PERFORMANCE

## Hydrovac

### Super Vacuum Return Units

Not one, not two, but three guarantees highlight the quality and performance of Hydrovac units.

1. 3-year wear-proof guarantee.
2. Guarantee of a minimum of 25 inches of vacuum at 70° F. against a sealed inlet.
3. Guarantee that vacuum will not recede to zero, with unit at rest, in any time under 5 hours.

Note these features of Hydrovac's exceptional design and construction:

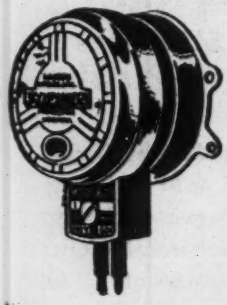
(1) Permoy Cast Iron Receiver; (2) Bronze Internal Parts; (3) Extra Large Shielded Bearings; (4) No Vacuum at Stuffing Box; (5) All facings machined; (6) Stainless Steel Rods; (7) Dash Pot Mechanical Valves; (8) Stainless Steel Bushings; (9) Wide Clearance Between Working Parts.

***Get All the Facts Back of Hydrovac's Triple Guarantee. Write for the 4-page Bulletin 100-B.***

**AMES HYDROVAC INC.**

**290 SCHOLES STREET** **BROOKLYN 6, N. Y.**

*If your post-war planning calls for miniature motors, clock movements or time machines, get the latest information on*



# SYNCHRON

**SYNCHRONOUS, SELF-STARTING**

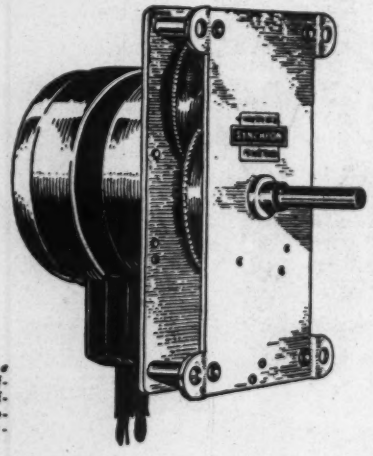
## TIMING MOTORS and TIME MACHINES

THE FAMOUS SYNCHRON MOTOR POWERS SYNCHRON TIME MACHINES

In this time-tested line you will probably find exactly what you want—but if your needs cannot be filled from standard models, our engineers will gladly design a power unit to suit your special requirements.

**STANDARD SYNCHRON MOTORS** are compactly built, with rotor and coil nested in a sturdy case 2 3/4" x 1 5/16"—with power to pull 8 oz. direct load continuously at 1 RPM. They are built for speeds of 1 to 300 RPM, clockwise, or counter-clockwise, in all voltages and cycles.

**STANDARD SYNCHRON TIMING MACHINES** are geared to operate at intervals of 1 RPM, 1 RPH, 1 RP12H, and 1 RPD. Any other interval desired can be supplied on special order.



*SYNCHRON Time Machines are self-starting, self-lubricating, synchronous, and long-wearing.*

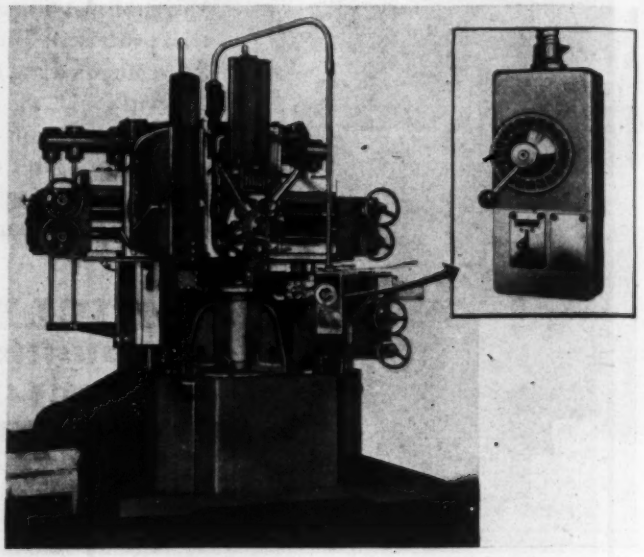
A new catalog-folder has been prepared on SYNCHRON Motors, Clock Movements, and Time Machines. Write for it.

**HANSEN MANUFACTURING CO., INC.**

**PRINCETON 6, INDIANA**

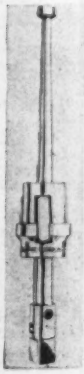
### Lathe Speed Control

No. 3034*—A new feature of all "Cut Master" vertical turret lathes, manufactured by the Bullard Co., 286 Canfield Ave., Bridgeport 2, Conn., is the "Pendant Control," which is said to provide a high degree of control and operating efficiency. A swinging arm carrying the pendant is mounted on top of the machine high enough to permit clearance of vertical heads when they are in maximum high position. The pendant is located at a convenient operating height. The arm may be swung from the right side of the machine to any convenient point over to the left side of the machine, thereby giving operating control at all times. According to the manufacturer, the design is a departure from conventional controls of this type, inasmuch as speeds are selected very rapidly by means of dialing. When the machine is in operation and a speed change is desired, the switch lever is thrown into brake position, the change of speed quickly dialed and the lever thrown back into clutch position. Gears are shifted through electrically-controlled, hydraulically-operated mechanisms. Self-interlocking design provides protection for the proper selection of gears.



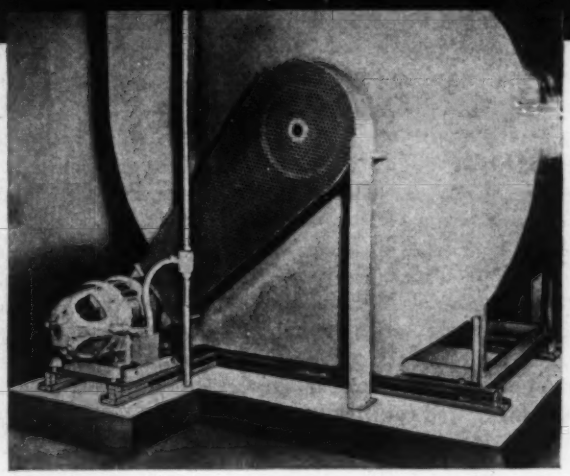
### Tube Expanders

No. 3035*—The "Model 16" tube expander is offered by Richard Dudgeon, Inc., Columbia and Broome Sts., New York 2, N. Y., for general boiler work, railroad maintenance, boilermaking, and boiler repair. According to the manufacturer, the expanders are compact, permitting them to work close to the boiler shell, rivet lines, or tubes grouped together; and they bear on the ends of tubes, do not draw tubes out of the tube sheet, and roll the tube ends for their full length. They are furnished for hand or combination hand and power use.



The expander may be dismantled for inserting new rolls. The frame holding the rolls is of one piece heat treated steel and the mandrel and rolls are of hardened tool steel.

# ISOLATE VIBRATION AND NOISE *from* FANS AND BLOWERS



Typical installation of fan and motor on Korfund isolating fan base.

KORFUND TWIN RAIL FAN BASE is a development in fan and blower isolation to assure efficient isolation of noise and vibration at an unusually low cost.

Interchangeable prefabricated parts are used throughout. It is light in weight, yet has great rigidity to vertical and lateral stresses. The Twin Rail Base is easily assembled and installed. Caps designed to hold fan and motor housings are securely clamped, yet can be repositioned by unlocking a single nut. Isolators provide uniform loading and can also be repositioned to compensate for unequal weight distribution.

*Write for Bulletin TR-800 for further information on Korfund Twin Rail Fan Base.*

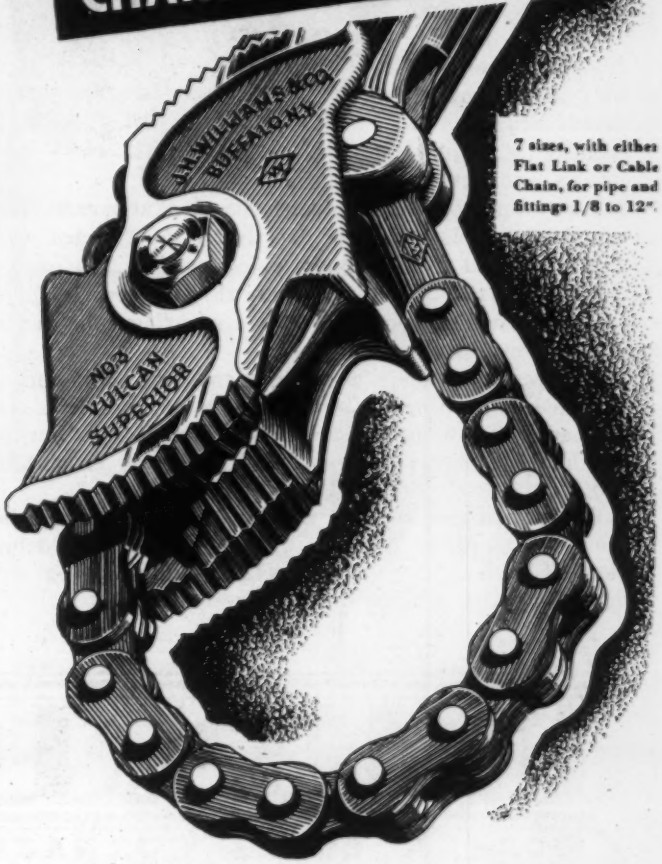
KORFUND
VIBRATION CONTROL
THE KORFUND COMPANY, Inc., 48-16 32nd ST., LONG ISLAND CITY 1, NEW YORK



# WILLIAMS

SUPERIOR DROP-FORGED TOOLS

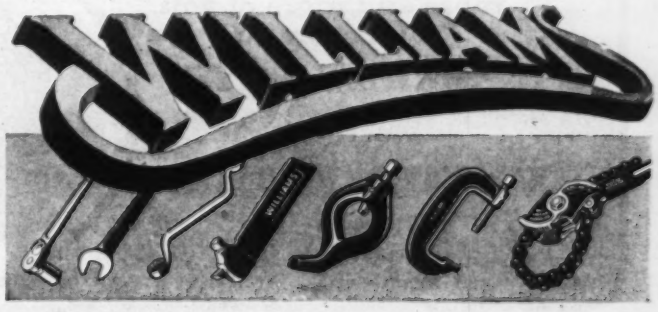
"VULCAN SUPERIOR" CHAIN PIPE TONGS




7 sizes, with either Flat Link or Cable Chain, for pipe and fittings 1/8 to 12".

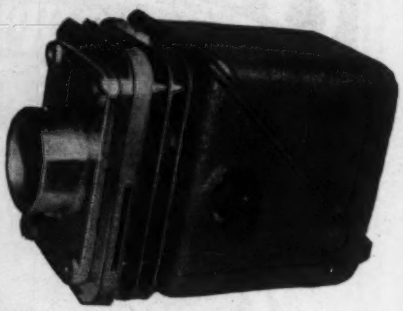
● Pipe or fittings—it makes no difference to "Vulcan Superior," the universal service tong. You can switch from one to another without adjustment or change of parts. And "Vulcan Superior" is the only chain tong with *reversible* pipe-and-fittings jaws. When one set of teeth begins to wear, simply remove the Through-Bolt and reverse the jaws. Sold by Plumbing Supply and Industrial Distributors everywhere. Literature on request.

J. H. WILLIAMS & CO., BUFFALO 7, N. Y.



### Photoelectric Flame Failure Safeguard

No. 3036—"Fireye Type F18T" flame failure safeguard is designed to provide explosion protection for industrial and commercial oil and pulverized coal burners. When flame fails, it cuts off fuel and sounds an alarm.



The unit has been designed to meet the requirements of the industrial user as well as the burner manufacturer. It consists of a phototube and amplifying system housed in a dust-tight aluminum case. The entire control is mounted directly on the furnace wall and is aligned in a manner which permits the photoelectric cell to observe the flame through a 2 in. pipe connection which serves as both a sighting tube and a support for the equipment.

A pyrex filter keeps the equipment dust tight and is mounted on a hinged shutter which permits it to be cleaned without shut down. A heat-absorbing filter in the lens system as well as a baffle system is said to protect the device from all radiated heat.

Other features include a pilot light which can be viewed through an angle of 180 deg and a time delay element which prevents the relay from dropping out during transient flame disturbances.

Specifications are as follows: supply, 115-230 volts, 50/60 cycle a-c; power consumption, 10 watts, output, single pole, single throw relay contact, 5 amp or ½ hp at 230 volts a-c operating range; the front of the control should be located within five feet of the flame which it is to monitor; weight, 12½ lb; ambient temperature range, 32-150F.

The manufacturer is Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.

### New Sealing Compound

No. 3037*—The development of a general purpose thread and gasket sealing compound, known as "Uniseal," has been announced by Parker Appliance Co., 17325 Euclid Ave., Cleveland 12, O.

This new organic product is said to produce a seal which is proof against air, water, steam, gas, gasoline, oil, hydraulic fluids, and the aromatics. Thorough testing has shown virtual insolubility in gasoline, kerosene, Stoddard solvent, benzene, xylene, carbon disulfide, the ketones, acetones and the various aromatic aviation fuels, according to the manufacturer.

It is a paste of uniform consistency and does not contain any free metallic particles.

Other features claimed for this product are good antiseize characteristics which aid in the assembly of threaded fittings, solubility in alcohol and carbon tetrachloride which simplifies any cleanup which might be necessary, and ability to withstand severe conditions of vibration and temperatures above 300 F.

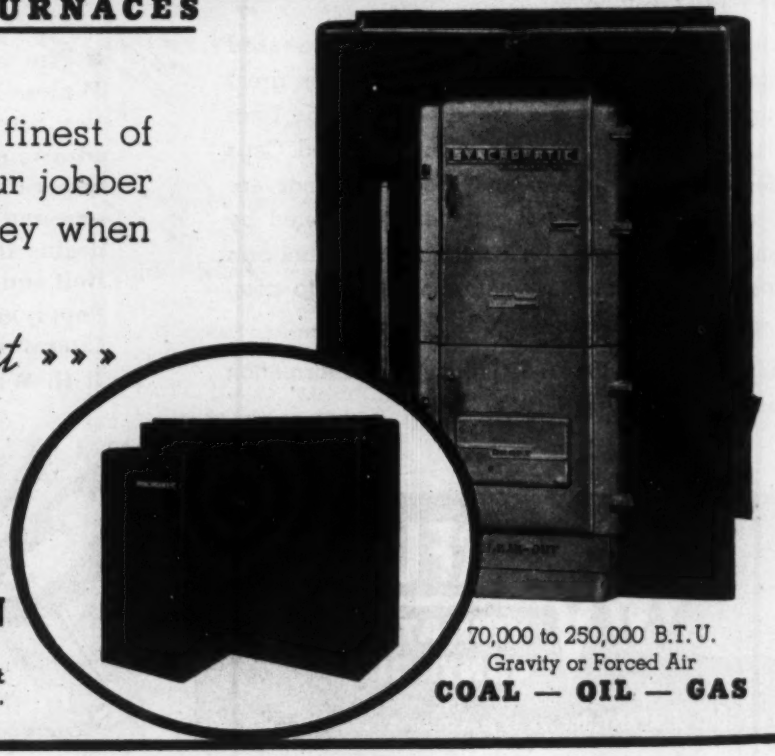

SYNCROMATIC

MODERN STEEL FURNACES

YOU'VE seen these finest of steel furnaces at your jobber —you've made money when you installed them!

*We're glad that »»»*

more and more of you are becoming "SMART BOYS"



70,000 to 250,000 B.T.U.
Gravity or Forced Air
COAL — OIL — GAS

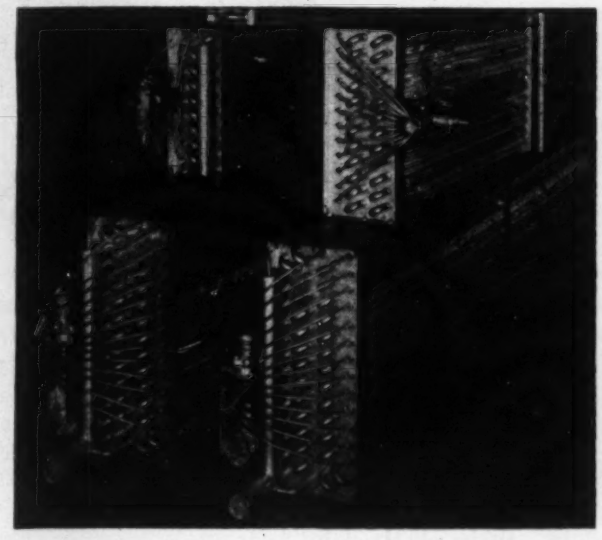
SYNCROMATIC CORPORATION

Factories: Milwaukee and Watertown, Wis.

Offices: 5110 N. 35th Street Milwaukee, Wis.

# COILS
## FABRICATED TO SIZE

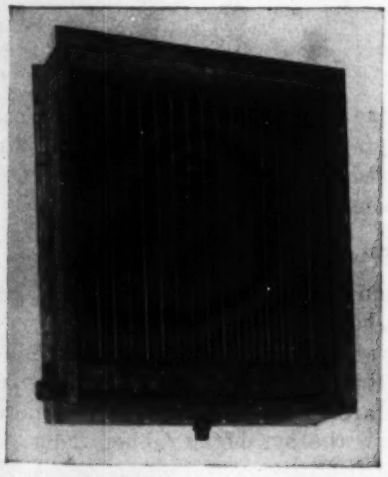
All Monsoon coils can be fabricated to specification in any size or shape for early delivery.



Monsoon Direct Expansion Coils and Coils for Water Cooling— Available in a wide range of sizes with circuits designed to provide for even distribution of liquid. Prompt delivery.

### TYPHOON Products

- **Prop-R-Temp** Self-Contained Air Conditioning Units, 3 and 5 tons
- **Typhoon** Evaporative Condensers
- **Typhoon** Spray Coolers (Air Washers)
- **Prop-R-Temp** Air Conditioning Units
- **Monsoon** Heating Coils (2-Header and Non-Freeze Types)
- **Monsoon** Direct Expansion Coils
- **Monsoon** Water Coils (Continuous Tube and Free Drain Types)



Monsoon Heating Coils—Two header and non-freeze types with inner tube steam feed. Extended surface coils permit high rate of heat transfer and remarkably low resistance to airflow. Available in a wide variety of sizes for prompt delivery.

**ICE-AIR CONDITIONING CO., INC.**

794-6 Union Street • Brooklyn 15, N. Y.

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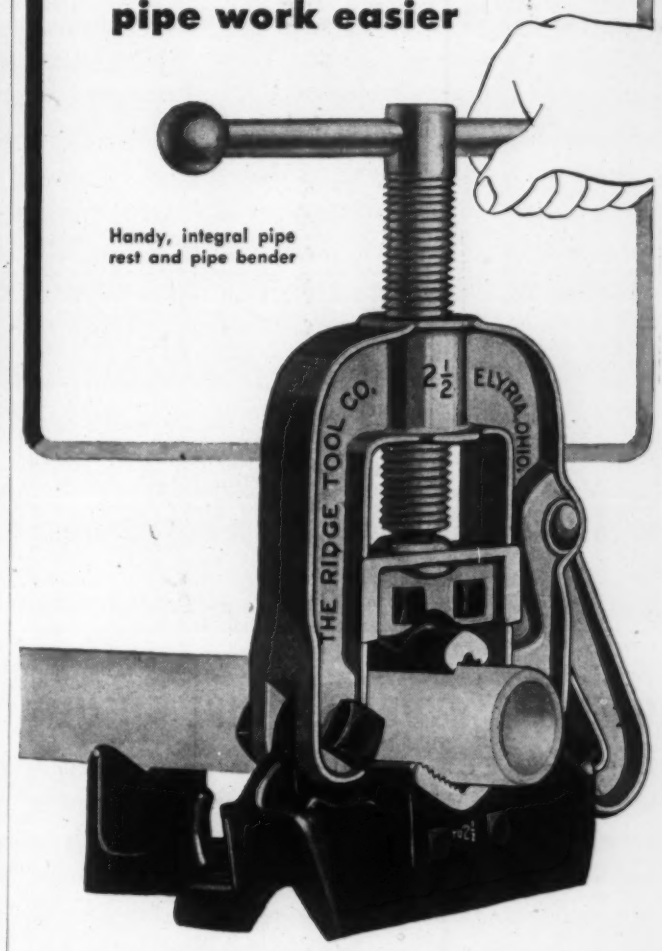
**This handy Red-Top**

**RIDGID**

**yoke vise makes your pipe work easier**



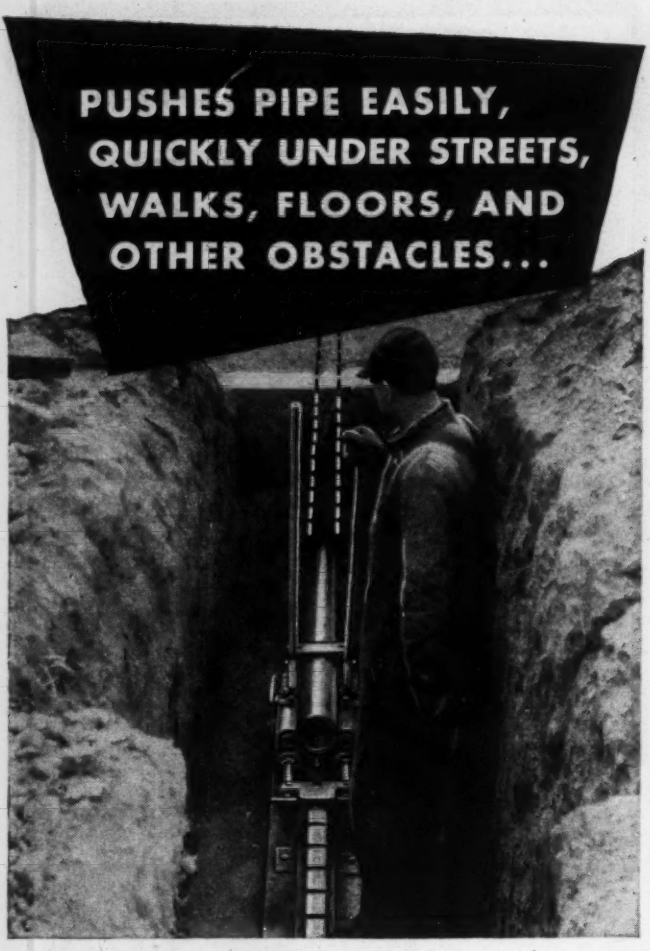

● Look for the red yoke on a black base when you buy a bench vise—for this sturdy RIDGID of strong special malleable offers you unusual convenience. It has an integral pipe rest for easier cutting and threading; it has a handy pipe bender. Its tool-steel LonGrip jaws are easy on polished pipe. It's more for your money—buy in any of 8 sizes for pipe to 6 inches, at your Supply House.

*RIDGID Vises, Yoke & Chain in 9 styles, 23 sizes.*

**RIDGID**

**WORK-SAVER PIPE TOOLS**

THE RIDGE TOOL COMPANY • ELYRIA, OHIO, U. S. A.




## GREENLEE HYDRAULIC PIPE PUSHER

Here's how you can cut costs, save time on underground pipe installations. With a GREENLEE Hydraulic Pipe Pusher *one man* can push pipe through the ground *easily, quickly* — under obstructions!

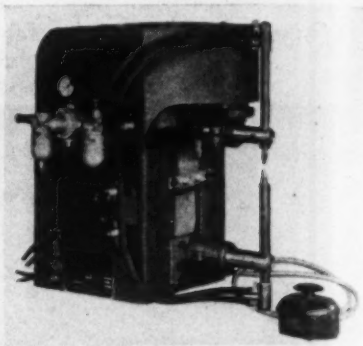
Save the time, work and inconvenience to all caused by the old methods of tearing up floors, lawns and pavement. Eliminate tedious back-filling, tamping, tunneling, repaving (just a short trench accommodates the pusher).

Save with the GREENLEE which often pays for itself on the first few jobs used. Learn all about this compact, portable, powerful pipe installing equipment . . . get free Folder S-117. Greenlee Tool Co., Division of Greenlee Bros. & Co., 2342 Twelfth St., Rockford, Illinois, U.S.A.

REGISTERED TOOLS
GREENLEE
FOR THE CRAFTSMAN


### Automatic Spot Welder

No. 3038**—A 7½ kva "Midget" automatic bench type, air operated spot welder is now in production at the Universal Welder Corp., 731 Carnegie Ave., Cleveland 15, O. Four steps of adjustable weld heat control deliver a secondary maximum of 12,500 amp so that it may be used to weld two thicknesses of 16 gage clean sheet steel.

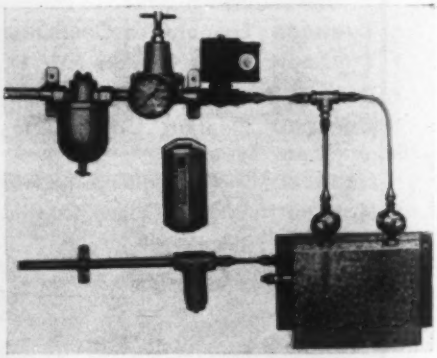


An air accessory unit consisting of an air filter, air regulator, pressure gage and air lubricator is designed to provide clean lubricated air to the air cylinder. Operating equipment includes an improved pressure switch, four way solenoid air valve, a heavy duty butt contact type inbuilt welding contactor, an air flow regulating valve for adjustment of point impact speed, a convenient foot switch, and water cooled electrode holders for No. 1 Morse taper welding tips.

Standard units have a throat depth of 9 in. Up to 16 in. can be obtained by factory modification of the upper cylinder press head mounting. The lower arm is adjustable up and down for a wide range of work.

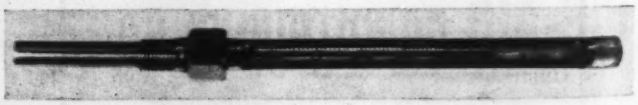
### Industrial Humidifying Unit

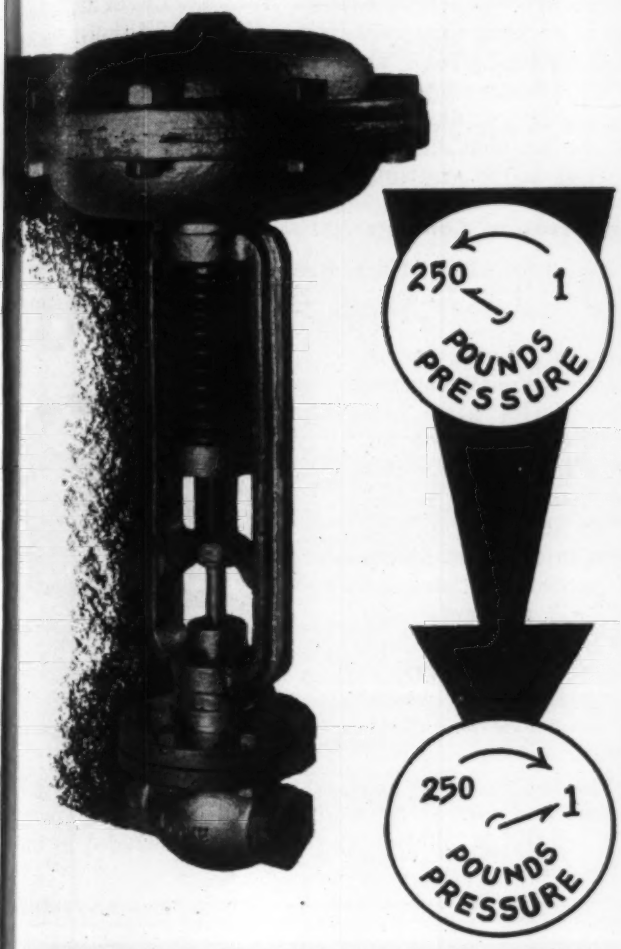
No. 3039—The new industrial humidifying unit produced by Spraying Systems Co., 4031 W. Lake St., Chicago 24, Ill., is said to introduce a departure from conventional types in that the entire unit is delivered ready for installation. Made in two or four nozzle units with humidistat control, set at various angles to increase moisture distribution. Siphon type humidifying nozzles are used which utilize compressed air, mixed externally, producing a fine spray. A complete two-nozzle unit is shown here.



### Small Thermometers

No. 3040—For accurate temperature indication and for use where large, heavy thermometers are not suitable, the H-B Instrument Co., 2518 N. Broad St., Philadelphia 32, Pa., is offering a line of "Midget" industrial thermometers which are said to be especially suitable for use in distilleries, the synthetic rubber industry, petroleum plants, and in experimental work.






*with THIS LOCKE*
## No. 25 REDUCING VALVE

Single-seated, self-contained, this Locke reducing valve holds true, steady pressure on low pressure side; reduces from 250 pounds to as low as one pound.

Locke Valves Possess Histories of 40-50 Years Continuous Operation Without Change!

Sturdy, hand machined at valve seat, piston and springs, this valve retains inherent sensitivity throughout its long life.

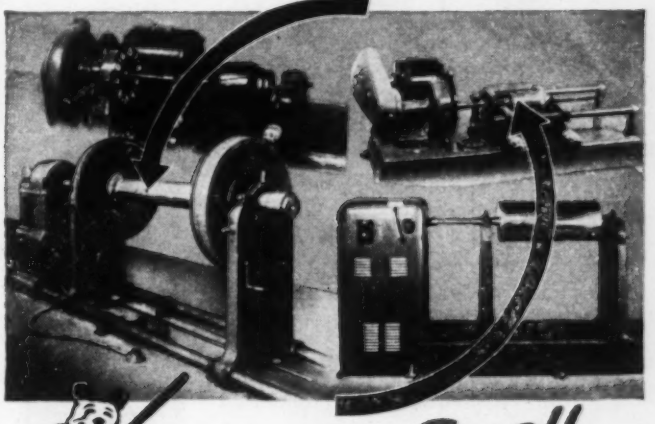
DIVISION OF THE H. T. WILSON MACHINE CO., INC.

# LOCKE
# REGULATOR
## COMPANY

WALTER AND OSBORNE STREETS
SALEM, MASSACHUSETTS

MODEL REGULATORS · DAMPER REGULATORS · FAN ENGINE REGULATORS · BACK PRESSURE VALVES · BALANCED VALVES · ELECTRIC VALVES · REDUCING CONTROLS FLOAT CONTROLS · PILOT CONTROLS · PUMP GOVERNORS · VACUUM BREAKERS ENGINE STOPS · MASTER REGULATORS · OIL CONTROL VALVES · SOLENOID CONTROLS

# For rotating bodies
# Large



# or Small

**NOW . . . A Complete Line of**
**BEAR *DY-NAMIC* BALANCING MACHINES**
***DRIVE OUT THE "WOBBLIES"***
***Quicker • Easier • at Lower Cost!***

REDUCE WEAR
MINIMIZE VIBRATION
ELIMINATE NOISE
INCREASE EFFICIENCY
CUT MAINTENANCE

Dy-Namic Balancing of all rotating parts, from tiny armatures to heavy railroad car wheels, is recognized today as never before as *essential* to longer machine life and more efficient operation. Bear's new, but thoroughly proven Balancing Technique, and lower cost, easier-to-operate Balancing Machines, now make Dy-Namic Balancing of *all* rotating parts a *fast, simple* and *economical* operation.

Write for FREE BEAR INDUSTRIAL BALANCING BULLETIN, containing complete information on this essential equipment. It explains the Bear Dy-Namic Balancing Principle which makes Dy-Namic Balancing so simple that operators can be trained in a few hours. Illustrates and describes Bear's complete line of machines for balancing every rotating part from 4 oz. to 4000 lbs. Tells how you can cut the time and cost of Dy-Namic Balancing.

**BEAR MFG. CO., Dept. HPA,**
**Rock Island, Illinois**

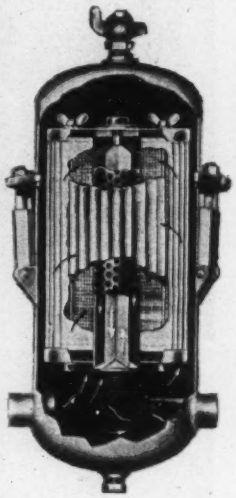
1184

**BEAR**
DY-NAMIC BALANCING MACHINES

The thermometers are provided with a lens-front yellow back tube and scale engraved on glass. Scale ranges from —30 to 77 F and thermometers are available in both straight and angle types.

### Liquid Filter

No. 3041—The Dollinger Corp., 11 Centre Park, Rochester 3, N. Y., now offers the "Staynew Model ELS" filter which is said to incorporate a new and superior design of filter insert. The assembly of the insert consists of inner and outer radial finned forms of wire cloth. The outer form on which the filtering media is crimped slips over the inner form. Top and bottom plates and seal gaskets are then applied, and the whole assembly is held in place by through bolts.



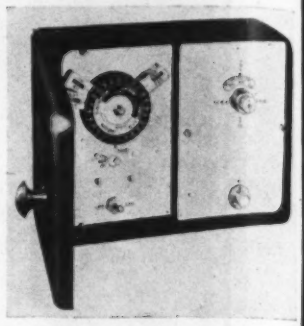
The new type of insert, known as the "Slip-On," is said to permit the use of practically any type of filtering medium obtainable in sheet form that can be crimped. It is also claimed that changing the filtering medium is simple and quick and that spare insert outer forms (relatively inexpensive) may be stocked in a variety of media for instant use, thus making the unit a versatile liquid filter with a broad range of applications in the industrial field.

### Packaged AC Unit

No. 3042—The Curtis Refrigerating Machine Div., Curtis Mfg. Co., 1950 Kienlen Ave., St. Louis 20, Mo., has announced a new and improved model of their packaged air conditioning unit. A complete air conditioning sytem (in one compact unit) which cools, dehumidifies, circulates, and filters the air is said to be provided. It can be adapted for heating and humidifying also, if desired, and is available in 3 and 5-ton capacities.

### Temperature Controls

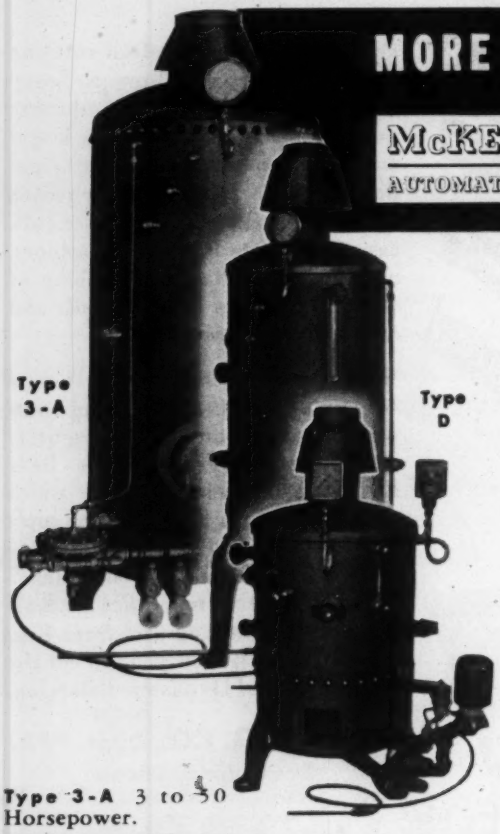
No. 3043—The Miller Heat-O-Meter Co., 1434 W. Atkinson Ave., Milwaukee 12, Wis., is now producing two new, improved temperature controllers which are said to provide important additional features. The "Series QD2" unit includes a new and improved dual time switch for turning the burner off at night and turning it on in the morning for a morning "pick-up" run. A mechanism for cycling a burner on and off during the day in accordance with weather conditions is included. Also included is a summer-winter switch.



The "Series QD3" unit, which has been designed for commercial stokers, is equipped with a built-in "hold-fire" control in addition to the features included in the other series.

The units are a new type of time cycle heat control


MORE and MORE HEATING CONTRACTORS are installing Gas-Fired McKEE AUTOMATIC "STEAMBOILERPLANTS"




Type 3-A 3 to 30 Horsepower.
Type D ¾ to 7 Horsepower.
Type C Same size as Type D, but faster steam, ideal for gravity return.

HERE'S WHY — These men know that McKee-Eclipse has had long experience in working with heating engineers and contractors on steam-generating equipment problems. Also that McKee-Automatic "STEAMBOILERPLANTS" offer this unmatched combination of advantages:— a complete Eclipse Factory-Built Unit, ready to install; Economical, due to use of small, long tubes. Complete line for generating process steam, garment pressing, compression molding, food, chemical, metal and other steam processes. *Write today for complete information. For your special steam-generating requirements, call our engineers.*

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ROCKFORD If it's for Gas—buy Eclipse ILLINOIS

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Built for steam pressures up to 125 lbs., these sensitive, quick-acting controls function upon a drop of air or liquid temperature of as little as ½°. Close, dependable regulation of temperature to the desired setting is assured.

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⅜" Orifice. Standard range of 130° to 165° F., plus special ranges.

**SERIES 150 CONTROL**
Operates on temperature drop of 1° or less. Standard range—130° to 150° F., plus special ranges.

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3738 N. Holton Street,
Milwaukee 12, Wisconsin

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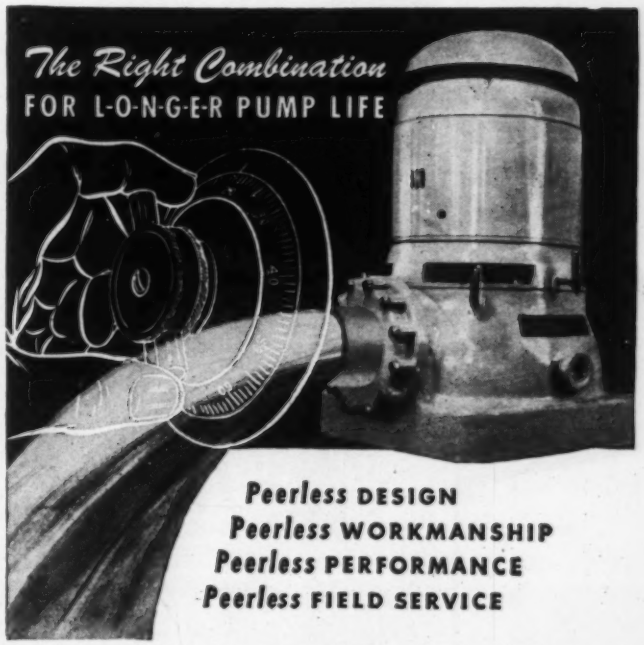


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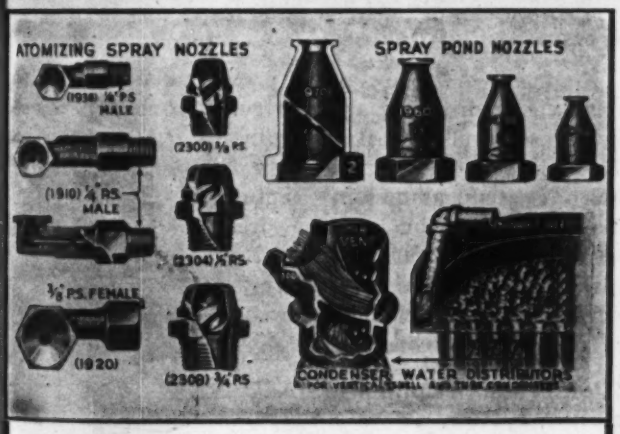


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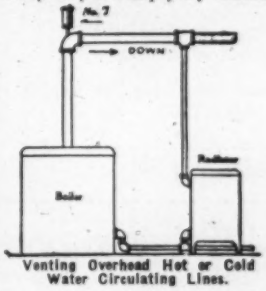
Don't fight air pockets or traps in hot or cold circulating lines. "Get that air out of there" *and keep it out* simply by installing the No. 7 Maid-O-Mist Automatic Air Vent. This reliable air vent has a self-closing float-controlled valve and is designed especially for circulating pipe lines, convector radiators, unit heaters, cooling manifolds, tanks, diesel engines, or any other application where air pockets or traps retard the free circulation of liquids. Now available in bright brass finish. For pressures up to 75 pounds.

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AUTOMATIC HUMIDIFIERS FOR ALL TYPES OF HEATING SYSTEMS

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## Is Your Fuel Consumption Up? Is the Rate of Transfer Slow? Do You Know Why?

Sludge—Internal friction—Grease Disturbed resistance balance — Bad Traps — Corrosion — Boiler carryover—are some of the answers.

Steam or hot water distribution systems all suffer from one or more of the above ills, mainly, BECAUSE NO TOOL for their elimination has been brought to your attention. THERE IS SUCH A TOOL—RYDAL SERVICE.

We know these troubles exist, and will continue to exist, unless you have a first hand acquaintance with RYDAL SERVICE, the proven operation that cleans the entire system internally and restores your plant to the original efficiency it had when new.

RYDAL SERVICE methods are proven, safe, and guaranteed to satisfy. The more difficult the job, the better we can serve you. We use tested and perfected solutions, which are:

**RID SLUDGE - - RYDDURT - - RYDLYME**
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All help the wise engineer out of trouble.

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for regulating the operation of stokers, oil burners, etc., used to heat multiple occupancy buildings where it is difficult or impossible to find a suitable location for a room thermostat. They provide the operator with a means for regulating the quantity of heat supplied to the building in accordance with outside temperature conditions.

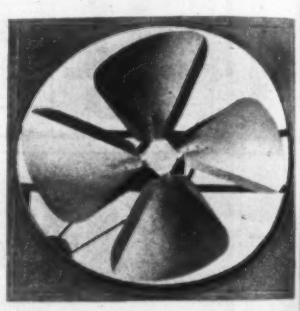
Heat is supplied to the building in metered "shots" or impulses. The number of firing cycles per hour is determined by the manual setting of a dial which can be varied in accordance with weather conditions.

### Electronic Switch

No. 3044—A new electronic switch (Model No. 8336) is announced by United Cinephone Corp., Torrington, Conn. This unit has been designed for 30 amp, and due to the use of a relay with contacts which are hermetically sealed, can also be used in the presence of explosive gases. These switches are used primarily for pressureless limit switching, floatless control of liquid levels and to eliminate contact arcs and welds.

### Propeller Type Fan

No. 3045—Holcomb & Hoke Mfg. Co., 1545 Van Buren, Indianapolis, Ind., has announced a new propeller type ventilating fan known as the "Silent Breeze." It is made for both home and industrial use, in sizes to meet the ventilating requirements of large industrial and commercial plants, theaters, hospitals, schools, etc. One outstanding feature is said to be the long balanced axle shaft designed for low noise level operation. Rated capacity of the various sizes of fans is from 7000 to 21,000 cfm.



### Pressure Relief Device

No. 3046—A "throw-away" pressure relief device for small air conditioning and refrigeration units is offered by Black-Sivalls & Bryson, Inc., 7501 E. 10th St., Kansas City 3, Mo. Coated aluminum rupture disks are used for bursting pressures of 150 to 500 lb and silver disks are used for bursting pressures of 250 to 500 lb. The body of the unit is of brass.

### High Pressure Condensate Return System

No. 3047—A new method of draining condensate from process equipment and returning it to the boiler room under pressure has been developed by the Cochrane Corp., 3131 N. 17th St., Philadelphia 32, Pa. The unit includes a centrifugal pump which energizes an eductor, which in turn pumps the condensate from equipment drainage return lines directly into the boiler, against boiler pressure, and in a closed circuit.

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**Invites Applications from Capable Mechanical Engineers**

OPPORTUNITIES are being offered to Engineers who can design and/or prepare engineering drawings for industrial buildings and their facilities. Assignments are not for specific projects but are in our regular engineering staffs in long established offices, located on the East Coast, Central West, Gulf Coast and West Coast.

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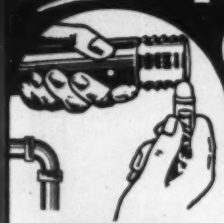

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Just rub 3 or 4 strokes across pipe threads. It spreads and fills threads when turned.

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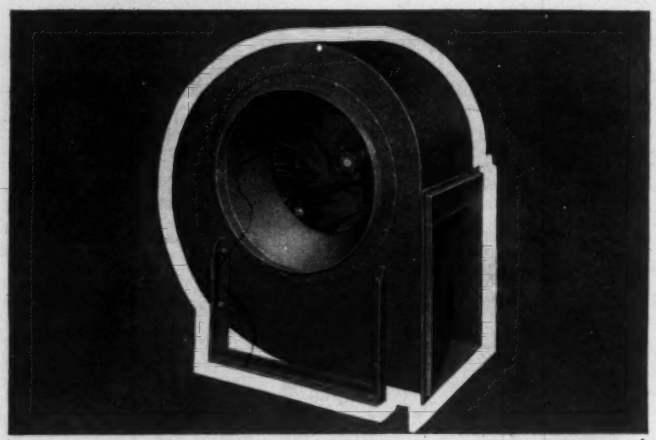

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In all sizes, wheels 12 to 72 in.

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Domestic and industrial models now available

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Dept. BB-830. Established 1887. West Bend, Wis.

A GEHL WINS FRIENDS WHEREVER IT GOES

## Circulating Pump

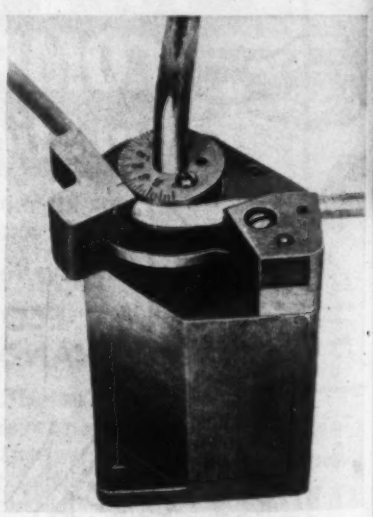
No. 3048—The balanced inlet impeller of a new circulator, for hot water or for heating systems, is made up of a die cast bronze hub with side flanged cover plates. An exceptionally close fit between the outer diameter of the impeller and bored diameter of the body is claimed. Combination seal ring and metallic packing are used for water exclusion and a grease-retaining bearing system.

The new circulator has a conventional flanged body for attachment to the heating system, and all parts are completely interchangeable with those of a similar model and number. Standard models are furnished with spring-mounted, vertical sleeve bearing, 110 volt, 60 cycle, single phase, fractional hp motors and with automatic reset overload relays. Electrical knockout boxes reduce transmission of noises between motors and heating systems.

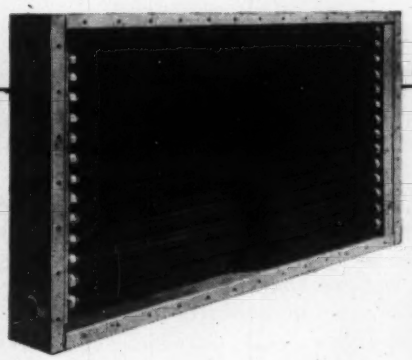
These vertical models are made in 1, 1¼, 1½ and 2 in. pipe sizes. Horizontal models are available for 2½ and 3 in. sizes. The manufacturer is the Triplex Heating Specialty Co., 252 N. Grant, Peru, Ind.

## Hand Bending Tool for Small Tubing

No. 3049—A new hand bending tool, which permits many kinds of small tubing to be curved to any desired angle, has been developed at the Glenn L. Martin Co., Baltimore, Md. The tool consists of a steel base which may be used in a vise or clamped onto a bench; a revolving radius rod equipped with a handle for turning; a stop block which guides the tubing around a bend roll centered on top of the base. This roll, cylindrical in shape and also grooved, has a top plate scribed in 360 deg. A measuring point is marked on the movable radius block. The radius and holding blocks and the roll are said to be so grooved as to prevent crushing or change in section of the tubing.



In operation the tubing is inserted in the groove of the stop block and the movable block which has been returned to the zero degree point. The movable block is then pulled around the bend roll, being connected to the revolving radius rod, until the measuring point is directly opposite the mark of the angle desired in the bend roll.



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## FOR HEATING AND COOLING IN A WIDE RANGE OF SIZES

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*Pioneer Manufacturers of Square Finned Tubing in the United States*

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## SOL-VET "08"

**Find Out How This Water Treatment Formula Can Remove Costly Scale and Slime in Your Equipment**

● If scale, slime, rust, algae are clogging up the lines of your cooling towers, condensers and hot water heating equipment look into the advantages of SOL-VET "08". SOL-VET service, highly recommended by leading engineers, offers you the facilities of one of the best equipped water laboratories in the United States. Thorough testing of your water can help determine the right SOL-VET service formula that will prevent clogging—boost equipment capacity, save needless shutdowns for overhauling. Write today for complete data on SOL-VET service with free analysis and recommendations for your specific problems of removing scale and dirt.

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when used as directed, to all water conducting materials in water cooled equipment.

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## PERMANENT

# Industrial Filters

**FOR IMPROVED AIR FILTERING**
**— GREATER CAPACITY —**
**LOWER MAINTENANCE COSTS**

SPECIALLY DESIGNED for extra heavy duty and industrial air cleaning services, BADGER Heavy Duty Permanent Filters assure improved air filtering, lower air resistance, greater dust-holding capacity, while definitely reducing costs of maintenance. In addition, longer life is a certainty. Available in 2" and 4" sizes.

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# EFFICIENT ECONOMICAL

De Luxe type WK Pressure Actuated Water Regulating Valves for Freon, Sulphur or Methyl, are pilot operated, modulating. Standard adjustable opening range from 50 to 150 lbs. Factory set to open at 90 pounds. Precision engineering and individual testing for low cost, satisfactory performance. Available in sizes of ¼ to 2 inches FPT. Simple adjustment—easily serviced.

***Other sizes and types are also available.***

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**2100 INDIANA AVE. CHICAGO 16, ILL.**

**COMPRESSED AIR LINE PURIFICATION YOUR PROBLEM?**

***Here's the Answer...***

The new Bird-White Pur-O-fier A-1 assures you of positive elimination by turbo-rotor centrifugal action of all free moisture, oil and foreign matter in small compressed air or gas systems. It operates with from 1 to 5 cubic feet of air (1 to 75 p.s.i.) and for intermittent operation is extremely sensitive.

Among many other uses this new unit is ideal for protecting air pressure operated machinery and instruments from corrosion and gumming.

For complete specifications and applications write today for Bulletin No. 11.

Bird-White Pur-O-fiers are also available in other models for purification of large volumes of compressed air or gas. Ask for Bulletin No. 10.

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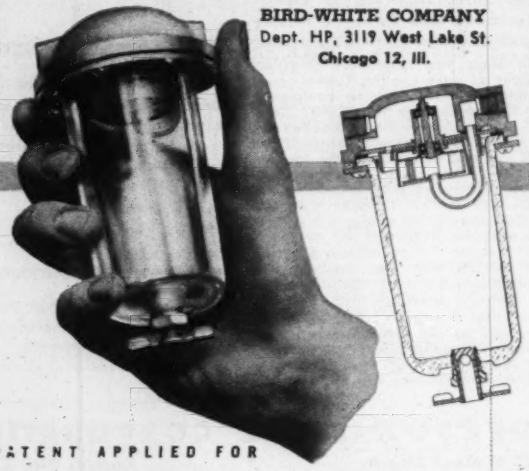

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THE AUER REGISTER COMPANY
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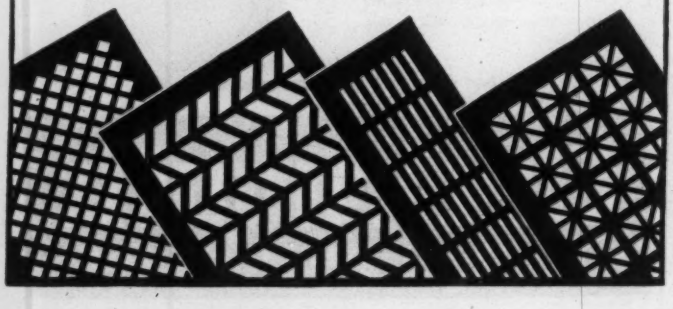



### Flange Jacks for Replacing Gaskets in Pipe Lines

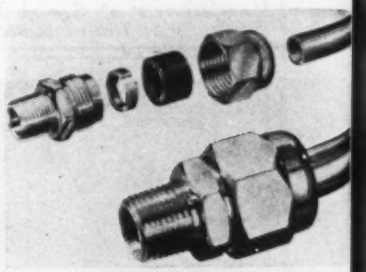
No. 3050—A tool designed to open flanges for gasket renewal has been announced by the T. G. Persse Co., 224 Glenwood Ave., Bloomfield, N. J.

Exertion of pressure is said to open flanges evenly, without shock, and bolt holes are maintained in continuous alignment. Freedom from sparks (an important factor when working on inflammable lines or in the presence of gas fumes), and no damage to flange faces, together with a saving in time and labor, are among the many advantages claimed for this tool.

The jaws are one-piece steel forgings. Screw points are case hardened and the standard size jack will open 2 to 20 in. diameter flanges.

### Fitting for Tubing

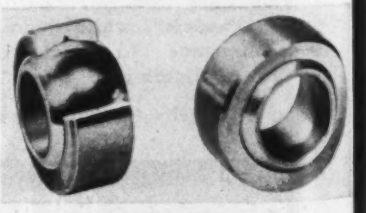
No. 3051—"Flexigrip" tubing fittings designed to eliminate end preparation or soldering of the tubing and yet produce a strong, leakproof and flexible joint have been announced by Gustin-Bacon Mfg. Co., 1412 W. 12th St., Kansas City 7, Mo.



The fitting, made in standard sizes from ⅛ to 1½ in. OD, consists of four parts—the body, a gripping ring, synthetic rubber gasket and nut. To attach the fitting, the nut (with gasket and ring inside) is slipped over any plain end tube, cut to desired length. The tubing end is inserted into the body as far as it will go and the nut tightened. Tightening the nut compresses the ring into a tight grip and molds the gasket around the ring for a tight seal. These fittings are available in brass, aluminum or steel.

### Self-Aligning Bearing

No. 3052**—A spherical bearing, which has been used extensively in Army Air Force planes, is now available to manufacturers of equipment using self-aligned bearings or rod ends with self-aligning bearings installed.



Offered by Halfco Products Co., 5341 San Fernando Rd. West, Los Angeles 26, Calif., the unit is made from a one piece bronze outer race into which is pressure-

Chromy says:

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CHROMALOX
Electric Centrifugal
UNIT HEATERS

Effectively heat shop-floors, factories and other large areas. Powerful twin-blowers force air through CHROMALOX Air-Blast Electric Heaters. Adjustable outlets distribute warmed air over broad areas. Ducts may be used to carry blast to desired locations. In 15, 20, 30 and 40 Kw—230 or 460 V sizes with thermostat heat controls. For details, write for Catalog 42 and "100 Ways to Apply Electric Heat" booklet.

EDWIN L. WIEGAND CO., 7610 THOMAS BLVD., PITTSBURGH 8, PA.

CHROMALOX SB-2

ELECTRIC HEATING AT ITS BEST

Janette Blower Wheels

**For Over 20 Years . . . Janette has been building Blower Wheels for discriminating users** who realized the importance of equipping their products with wheels of highest quality.

There are 63 single inlet and 22 double inlet wheels available, in 5-inch to 12-inch diameters, from 67 to 4620 c.f.m. capacities.

**We Solicit Your Inquiries** and the privilege of extending to you the benefits of our long experience in the building of wheels for motorized blowers.

**Ask For Bulletin 24-1**

Janette Manufacturing Company
556 W. Monroe St. Chicago 6, Ill.

Hot off the Press!

POST-WAR FAN and BLOWER BULLETINS

If you have need for the very latest industrial-commercial fan and blower information, you need one or more of these bulletins. They describe the tremendous air-moving advances which war necessity brought about. They're just off the press. They're free. Send for yours now.

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- ☐ 1202..COOLING, DRYING FANS
- ☐ 1302..PULLEY DRIVE, BELT-DRIVE, EXTENSION-SHAFT, SLOW TIP-SPEED FANS
- ☐ 1402..DUCT FANS
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Hartzell
PROPELLER FAN CO.
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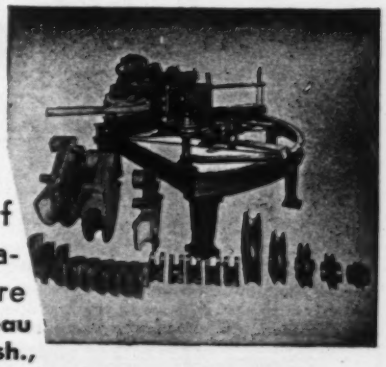
COLD PIPE, CONDUIT and TUBE BENDING MACHINES

12 types from which to select; hand operated capacities:- ¼ to 6" inclusive; motor operated:- ½ to 8" inclusive. Now indispensable to contractors, shipbuilders, ordnance plants and thousands of others. These machines will be essential also in industrial conversion after the war.

12,000 customers—and more—can testify to the indispensability of "American" machines. Here are a few users: Bureau of Ships, Wash., D. C.; Henry J. Kaiser Co., Calif:; Pacific Bridge Co.; Bethlehem-Hingham Shipyards; Hercules Powder Co.; Stone & Webster; E. I. Du Pont de Nemours & Co.; Crane Co.



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★ Propeller fan and blower types. Nine sizes of each.

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2. Goes on and off itself
3. Will heat any size area
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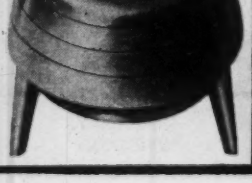
VORNADOFAN begins where other manufacturers leave off. Truly a triumph of air circulation—astonishingly quiet, economical and efficient. Penetration is three times greater than that of ordinary fans. Ask your distributor for a demonstration. You have to see it in operation, for there are no standards by which to compare VORNADOFAN.



15 GREAT MODELS FROM WHICH TO CHOOSE

Vornādofan
O. A. SUTTON CORP.
WICHITA, KAN.

inserted a hard chrome plate steel ball. It is said to provide extremely high load capacity and is designed for use where alignment is costly or impossible to attain, or where rigidity is at a premium.

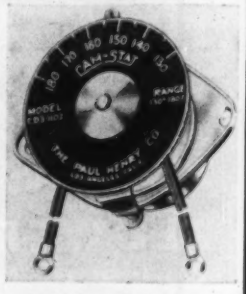
### Sealed Gasket

No. 3053—A serrated type gasket, known as "Bellow-seal," has been developed by the Goetze Gasket & Packing Co., Inc., 60 Allen Ave., New Brunswick, N. J. It consists of two discs of metal (Armco iron, low carbon steel, monel, or stainless steel) machined on their external faces and welded together around their outer periphery.

The gasket is said to combine the pressure and corrosion resistant qualities of metal gaskets with the light bolting requirements of a softer sealing medium. This, says the manufacturer, is due to line pressure entering the interior of the gasket and exerting an expansion pressure in excess of the required sealing pressure.

### Temperature Control

No. 3054—A new line of adjustable temperature controls has recently been announced by Paul Henry Co., 2037 South La Cienga, Los Angeles 34, Calif. A precise dial selection of the temperature control point with uniformity of dial accuracy in all units, tamperproof dial installation, and a ready adaptability to specially styled adjusting knobs and other design requirements are among the features claimed.




A wide choice of adjustable ranges is available between —50 and 600 F, with differentials as low as 1 degree. The "Cam-Stat" may be clamped on a tank or the element may be immersed in water. A variety of mounting means is available for adapting the unit to the control of air, gas, liquid or solids. Double break snap action contacts with a rating of 12 amp, 115 volts a-c or 28 volts d-c are incorporated.

### Crane Cab Cooler

No. 3055—A new air cooled conditioning unit for crane cabs working over ingot molds, soaking pits, or vats where acid or other fumes are present has been announced by the Dravo Corp., Machinery Div., 300 Penn Ave., Pittsburgh, Pa.

The unit, which is fitted to the top of the cab, is entirely self-contained and requires only an electric power connection for its operation. All equipment is enclosed in a steel frame and housing. The air supplied to the cab is cooled, cleaned, and constantly circulated. Acid fumes are said to be eliminated by a special fume absorber. Air filters are the standard throwaway type used in quantities in other steel mill operations. The

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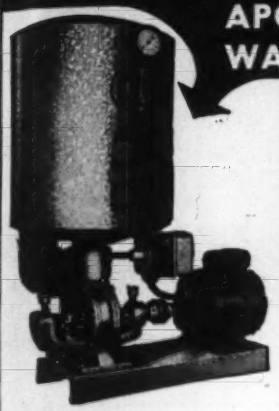
APCO *Pump-Master* WATER SYSTEMS



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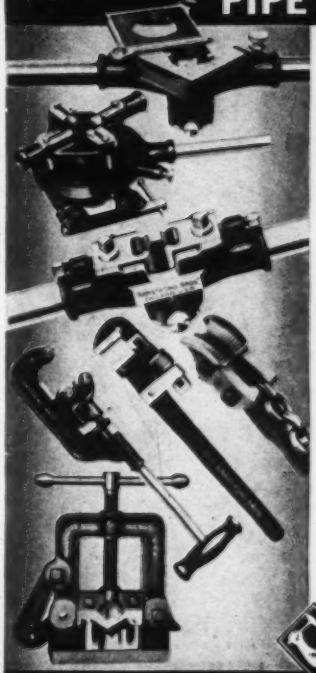
PIPE TOOLS



The "ARMSTRONG BROS." Line of Pipe Tools is the most extensive manufactured, including:

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- "Drop Forged," "Combination," "Saunders Type" and "Barnes Type" Pipe Cutters and Knife Blade Cutter Wheels
- Drop Forge Pipe Wrenches, Chain Wrenches and Chain Tongs
- Ratchet Pipe Reamers, etc.

Each is an improved tool —a handier tool with drop forged, hardened or alloy steel parts wherever they will add strength, balance or tool life.

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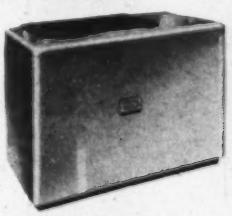

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It will pay you to investigate the profit opportunities of the Schelm "Polar Freez," cold-storage food cabinet now in demand by so many quality-conscious housewives, farmers, sportsmen, and commercial users. Here's a low-temperature unit that can be a real money-maker for you . . . an economical, convenient, long-wearing appliance you'll be proud to sell.

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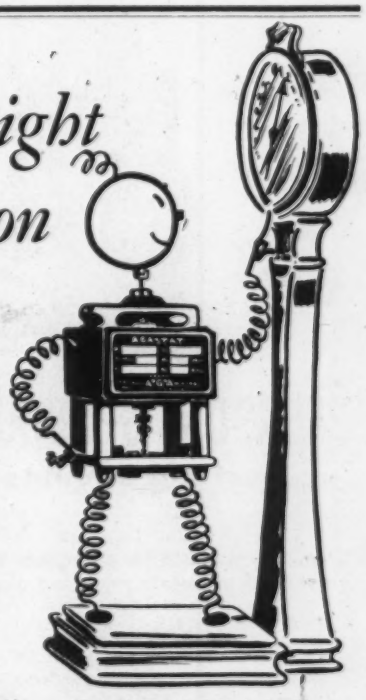

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